INSTRUCTION MANUAL

MOTOROLA

Digital RF MILLIVOLTMETER

S-1340A

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CHAPTER I

GENERAL INFORMATION

1.1 GENERAL

This RF Millivoltmeter provides digital readout of measurements from the low radio frequencies to the gigahertz region, over a voltage range of 200μV to 3 volts. It is a programmable, solid-state instrument of high sensitivity and accuracy.

The Voltmeter exhibits true rms response for input signals up to 30 millivolts, gradually approaching peak-to-peak above this level, calibrated, however, in rms of a sine wave.

The instrument is characterized by high input impedance (see Figs. 1 and 2), excellent stability, and low noise. A small edge-wise panel meter, calibrated in dBm, is included; this is necessary for zeroing the instrument (the digital display blanks out below 200 μV), and will also serve for comparative measurements of acceptable accuracy.

A binary coded decimal (BCD) output is provided at a rear connector, permitting the meter to be integrated in systems for driving printers, tape or card punches, data control units, and similar interfacing data equipment. As part of a system, the meter is also programmed and controlled externally as needed.

A linear dc output, whose level is proportional to the rf input voltage, is also provided at a rear connector. This may be used to drive a recorder, remote indicator, or other analog devices.

The unit offers a convenient and accurate means for making a wide variety of measurements. Typical uses of this instrument would include:

VSWR and return loss measurements using the RF Voltmeter with bridge methods, directional couplers, and adjustable or slotted lines.

Gain and loss measurements in wide-band amplifiers, including such design characteristics as stage gain, flatness of the pass band, upper cutoff or corner frequency, negative feedback factors, and other parameters.

Proper adjustment of tuned circuits in narrow-band amplifiers.

The adjustment, measurement of performance, and evaluation of parameters of rf filters.

Measurement of vswr or return loss and attenuation of rf attenuators.

Measurement of output levels of signal generators, adjustment of baluns, harmonic distortion of rf signals, and adjustment of circuits for minimum voltage (null) or maximum voltage (peak).

The standard features of the instrument are:

Programmable (logic level)
Measures from 200 μV to 3V* from 10 kHz to 1.2 GHz
True rms response to 30 mV**
Convenient push-button ranging
BCD digital output plus dc analog output
High input resistance, low input capacitance
Overload protection to 400 Vdc, 10 Vac
VSWR less than 1.2 up to 1.2 GHz

The characteristics of the instrument include: high reliability, fast warm-up (1 minute), long intervals between calibrations, plug-in PC boards for ease in servicing, light weight, and other advantages of solid-state design.

1.2 EQUIPMENT DESCRIPTION

The instrument is basically a programmable analog instrument with digital readout. It is available with a full range of options and accessories as described in Chapter II. Input range programming by logic level command is standard.

The instrument is sensitive, accurate, sturdily constructed, and protected against overloads. It will perform over extended

*To 300V, up to 700 MHz, with accessory 100:1 divider.

**To 3V, up to 700 MHz, with accessory 100:1 divider.

periods of time without failure or need for recalibration. It is packaged as a compact bench instrument that can be easily mounted in a standard 19-inch rack using an inexpensive hardware kit.

Important input and accuracy specifications are reproduced on a reference plate fastened to the exterior top cover of the instrument. Clips for holding out-of-use accessories are provided at the rear of the instrument. Calibration instructions are reproduced on the underside of the top cover of the instrument.

Standard accessories supplied with the RF Voltmeter include one each of the following:

RF Probe with low-noise cable and connector
50-ohm BNC adapter
Probe Tip (removable) with grounding clip lead

1.2.1 Wide Frequency Range

The calibrated frequency range of the instrument extends from 10 kHz to 1.2 GHz, with uncalibrated response to beyond 8 GHz. Relative accuracy above 1.2 GHz is typically $\pm$ 0.5 dB.

A 50-ohm BNC Adapter is supplied as a standard accessory with the instrument for 50-ohm voltage measurements up to 600 MHz. A correction curve (Figure 8A) is included for frequencies above 50 MHz. For higher-frequency measurements and for through-line voltage measurements the optional accessory, 50Ω type N Tee Adapter, is recommended. It is designed to compensate for the rf probe capacitance and to present a good vswr (better than 1.15) up to 1.2 GHz.

It may be used in conjunction with the Type N 50-ohm load for terminated voltage measurements. In a coaxial line its insertion loss is low; however, a chart (Figure 8B) is supplied showing loss vs frequency. See Figure 4 for typical vswr.

1.2.2 Wide Voltage Range

The Voltmeter has eight ranges, from 1 millivolt full scale to 3 volts full scale, arranged in 1-3-10 sequence. No attenuator attachments are required for measurements up to 3 volts. While this range is ample for most rf voltage measurements, the capability of the instrument can be increased to 300 volts (up to 700 MHz) by using the optional accessory, high Z 100:1 Voltage Divider. Use of the 100:1 Voltage Divider also increases the input resistance of the supplied RF Probe by a factor greater than 100.

1.2.3 True RMS Response

The Voltmeter provides true rms response for signal inputs below approximately 30 millivolts (below 3 volts, up to 700 MHz, with the high Z 100:1 Voltage Divider). As the input level increases, the waveform response gradually approaches peak-to-peak, calibrated on the indicator in rms. Thus, in addition to making precise sinusoidal voltage measurements at all levels, the instrument measures non-sinusoidal or asymmetrical signals within the rms region without loss of accuracy.

1.2.4 Low Noise

The RF Voltmeter has been designed and constructed to hold noise from all sources to a minimum.

The probe cable is of special low-noise design; a vigorous flexing causes only momentary, minor deflections on the most sensitive range. The supplied Probe is not sensitive to shock or vibration; even sharp tapping on the probe barrel causes no visible deflection on any range.

Amplification takes place at 94 Hz, reducing susceptibility to any 50 or 60 Hz line-frequency-related fields. A unique circuit reduces the low-level noise originating from the mechanical chopper and renders the instrument immune to changes in chopper performance that could occur with the passage of time.

1.2.5 Minimal Zero Adjustment

Zero adjustment is not required on the upper five ranges of the instrument. For measurements on the lower three ranges, the ZERO control is set on the most sensitive range before operation. This control balances out small thermal voltages in the probe elements and, once adjusted, requires only infrequent checking during the course of subsequent measurements.

1.2.6 BCD Output

The RF Voltmeter provides a serialized binary coded decimal output (4-line, 8,4,2,1) for connection to an external system. When the unit is an integral part of a system configuration, it may be remotely controlled and triggered automatically in synchronism with some system event.

For systems or external requirements, all input and output connections for the RF Voltmeter are made at the card-edge connector on the rear of the instrument. See Figure 11 for receptacle connections.

1.2.7 DC Analog Output

The unit also provides a linear dc output whose current capability of 1mA into 1000 ohms is extremely stable.

CHAPTER II

SPECIFICATIONS

Voltage Range: 200 µV to 3V

Full Scale Voltage Range: 1, 3, 10, 30, 100, 300, 1000, and 3000 mV.

dBm Range: -60 to +23 dBm

Frequency Range: 10 kHz to 1.2 GHz (uncalibrated response to approximately 8 GHz).

Accuracy:

at reference conditions

	10 kHz	150 MHz	700 MHz	1.2 GHz
300mV to 3V	1% fs plus			
200µV to 300mV*	1% rdg	3% rdg	10% rdg / 7% rdg	

*Below 1mV add ± 1% fs

Indicators:

Digital LED, 4 digits, f.s. counts of 3000 and 1000. Blanked at 5% over and below 20% f.s.; decimal point, units.

Analog	Miniature edgewise type, calibrated -9 to +3 dBm, 50 Ω.
Power:	115 or 230 V ± 10%, 50 to 400 Hz.
RFI:	There is no detectable radiated or conducted leakage from instrument or proble.
Temperature:	In accordance with ANSI (ASA) Spec. 39.7

Temperature Range	Temperature Influence	
	Instrument	RF Probe
Ref. 21° to 25° C	0	0
Normal, 18° to 30° C	0	± 1% rdg
Severe, 10° C to 40° C	± 1% rdg	± 4% rdg

Waveform Response:	True rms response for input levels up to 30 mV (3V to 700 MHz with 100:1 Voltage Divider), with transition to peak-to-peak (calibrated in rms at higher levels.
Crest Factor:	420 to 1.4 depending upon input level (see Table 2).
Input Impedance:	See Figures 1 and 2.

VSWR:	Less than 1.2 to 1.2 GHz (Return Loss greater than 23 dB). See Figures 3 and 4.
Power Sensitivity:	200 pW, minimum detectable power in 50 ohms.
Data Outputs:	1-2-4-8 BCD data, serial by digits. 1-2-4 range information. Overrange, underrange, encode complete. Logic 0 ≤ 0.7V; logic 1, 2.4 to 5.25V.
Commands:	Logic-level inputs select input ranges, mV, encode hold, encode trigger, manual disable, TTL compatible. Logic 0 ≤ 0.7V; logic 1, 2.4 to 5.25V.
Analog Output:	0 to 10 vdc, proportional to rf input voltage. 9 kΩ source resistance.
Dimensions:	5.2" H, 8.3" W, 11.5" D (132 x 211 x 292 mm).
Weight:	Net 9 lbs. 3 oz. (4.1 kg) (with standard accessories).
Accessories Furnished:	RF Probe with low-noise cable and connector assembly for measurements

from 10 kHz to 1.2 GHz; see Figures 1 and 2 for input resistance and capacitance.

Probe Tip. Removable Probe Tip with grounding clip lead; for use up to approximately 100 MHz.

50Ω BNC Adapter. Used for measurements up to 600 MHz with a 50-ohm system; for VSWR see curve of Figure 3.

Accessories Available:

Low Frequency Probe for measurements from 250 MHz down to 1 kHz.

Unterminated BNC Adapter for coaxial connection up to approximately 100 MHz or to 400 MHz when fed from a 50Ω source in an electrically short system.

100:1 Voltage Divider; attenuates input signal by a factor of 100 ($\pm$ 1%), permitting measurements up to 300 V, and extending the rms measuring range to 3V; increases input resistance by a factor of $>$ 100; operates from 50 kHz to 700 MHz. Maximum input potential, 1000 V, dc plus peak ac.

50 Ω BNC Adapter for measurements up to 600 MHz in a 50 Ω system.

RF Probe with low-noise cable and connector assembly for measurements from 10 kHz to 1.2 GHz.

Removable Probe Tip with grounding clip lead; for use up to approximately 100 MHz.

Type N Tee Connector; permits connection into 50 Ω line; required for measurements above approximately 100 MHz.

Type N 50 Ω termination for use with Tee Connector.

Unterminated Type N Adapter.

Storage container for accessories.

Rack-mounting kit (mounts left or right).

Dual rack-mounting kit.

IMPORTANT NOTE:

To fully exploit the capabilities of this instrument, the accessories listed below are required for the indicated ranges of operation.

Table 1. Required Accessories

MEASURING RANGE	REQUIRED ACCESSORY	REMARKS
100 MHz to 600 MHz	50Ω Adapter for shielded connection to 50-ohm line; other impedances available on request.	Supplied as standard equipment
Above 600 MHz	Tee Connector and 50Ω Termination for connection into 50-ohm line.	Available separately
1 kHz to 250 kHz	Low Frequency RF Probe	Available separately
Input levels up to 300V; rms response with levels to 3V	100:1 Voltage Divider; operates over frequency range from 50 kHz to 700 MHz	Available separately

Table 2. Crest Factors

VOLTAGE RANGES (mV) AND CREST FACTORS								
VOLTAGE RANGES (mV)	1	3	10	30	100*	300*	1000*	3000*
CREST FACTOR**	420 to 42	70 to 14	21 to 4.2	7 to 1.4	420 to 42	70 to 14	21 to 4.2	7 to 1.4

*With accessory 100:1 Voltage Divider (see Table 1).
**Maximum permissible ratio of peak to rms value of voltage.

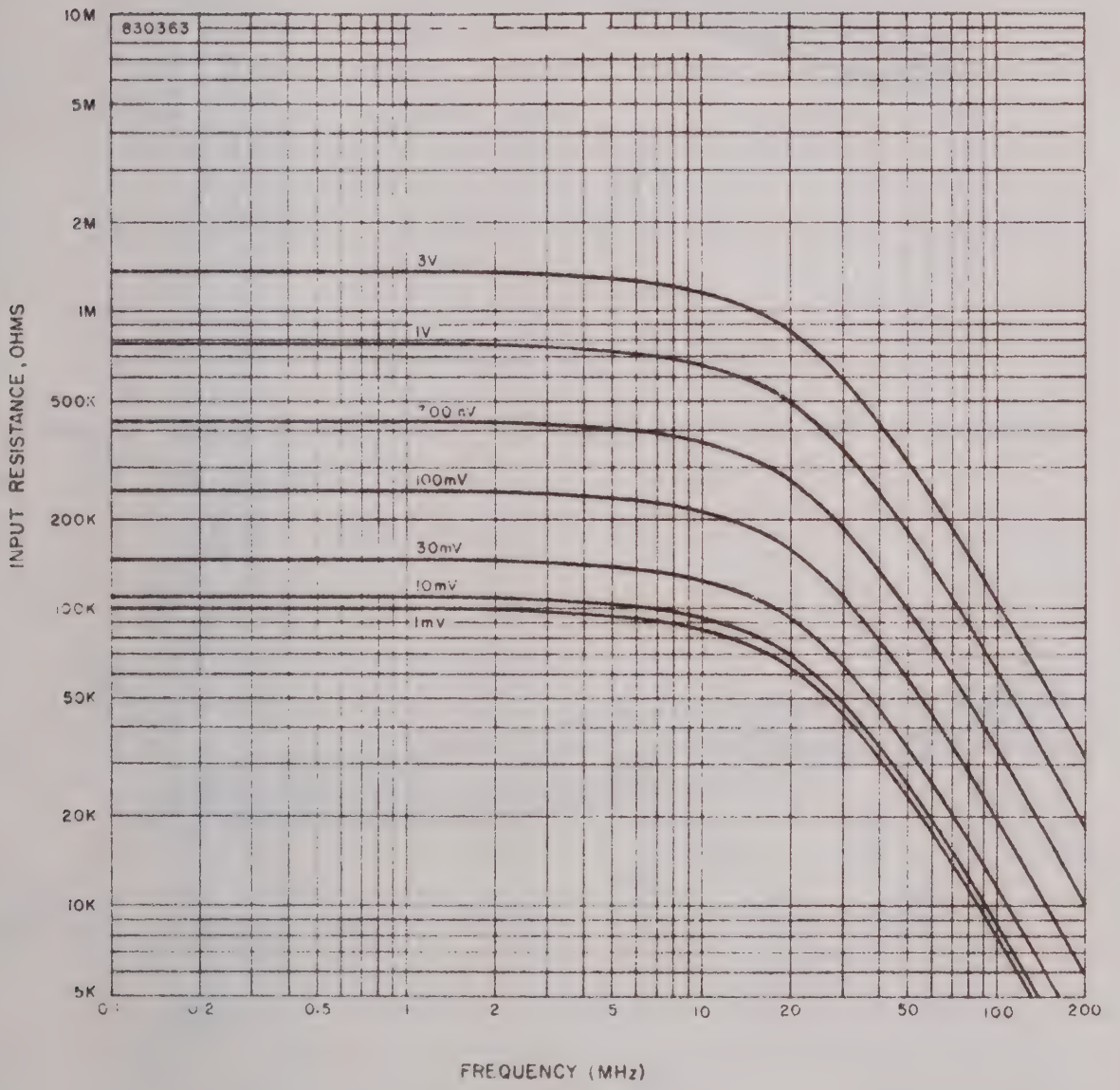


Figure 1. Input Resistance of RF Probe as a Function of Input Level and Frequency

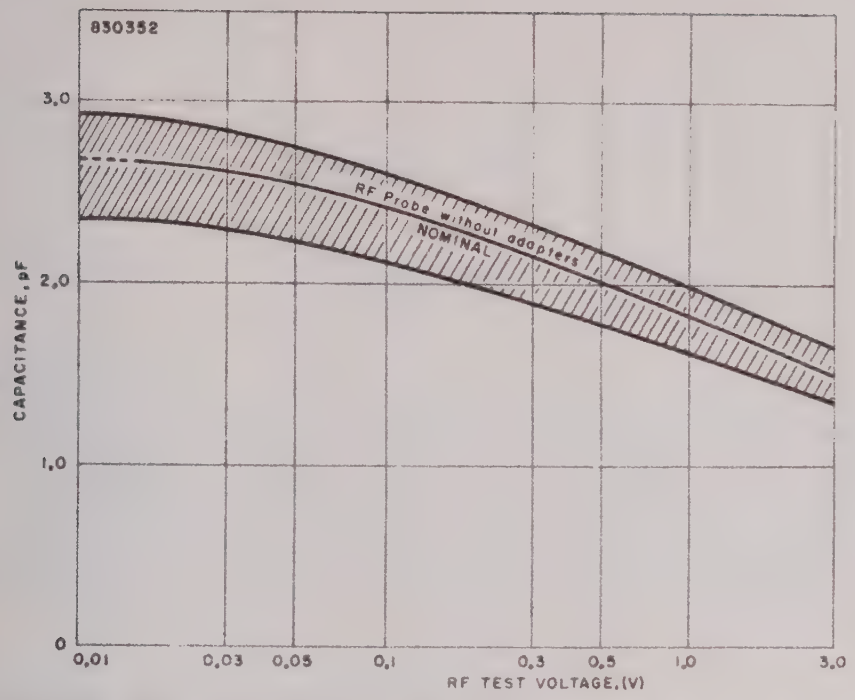


Figure 2. Input Capacitance vs. Input Level of Probe (Measured at 10 MHz)

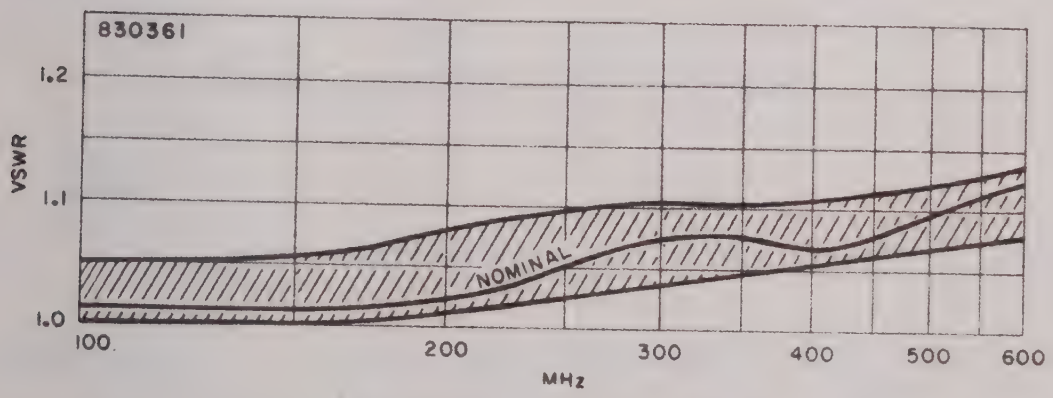


Figure 3. Typical VSWR of RF Probe with 50Ω BNC Adapter

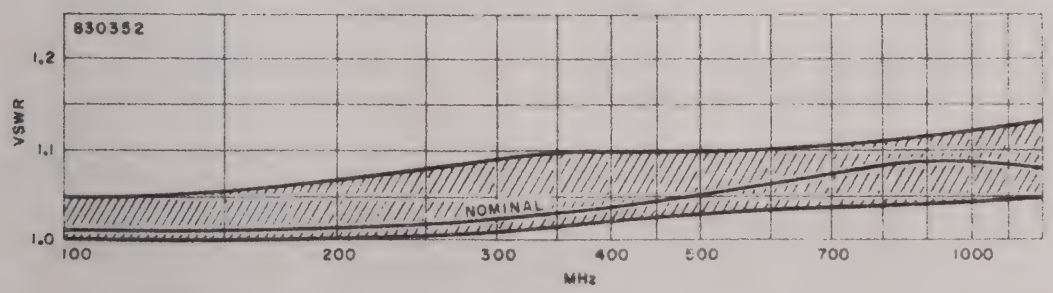


Figure 4. Typical VSWR of RF Probe with Type N Tee Adapter and 50Ω Termination

CHAPTER III

OPERATION

3.1 INSTALLATION

The RF Voltmeter has been inspected and tested at the factory before packing and is shipped ready for operation. If there is any indication of shipping damage, immediately notify the carrier before attempting to put the instrument into operation.

3.1.1 Operating Controls and Indicators

The controls and indicators are shown in Table 3 below.

Table 3. Controls and Indicators

ITEM	FUNCTION
Selector	This switch turns on the instrument power.
FULL SCALE Range	These range pushbuttons. (1, 3, 10, 30, 100, 300, 1000, and 3000 mV and (-50, -40, -30, -20, -10, 0, +10, and +20 dBm) select the operating range.
Indicators	
Digital:	LED, 4 digits, f.s. counts of 3000 and 1000. Blanked at 5% over and below 20% f.s.; decimal point, units.

Analog:	Miniature edgewise type, calibrated -9 to +3 dBm, 50Ω.
PROBE (Jack)	The probe cable connects to the instrument through this PROBE jack. Always check that the knurled ferrule nut of the probe cable connection is tightened when in use.
ZERO (Control)	This control is used to zero the instrument

The following items are on the rear panel:

Fuse Holder and Fuse	A fuse holder is located on the rear panel for installing either a 0.20 ampere, 115 V, or a 0.1 ampere, 220 V, Bussman MDL SLO-BLO fuse.
Slide Switch	Switch which is set to 115 V or 230 V, according to the available power source. Be sure that the proper fuse is located in the fuse holder.
Recorder Output Terminals	A DC voltage proportional to the indicator reading is available at these terminal. F.S. output = +10V Output resistance = 9 kΩ
Component Holders (Clips)	Three component holders or component clips are located at the rear panel for securing accessories which are not in use.

REMOTE CONNECTIONS (Use with an Amphenol 225-2221-101 connector or equivalent)

A card edge connector is mounted at the rear of the instrument. See Figure 11 for the pin designations.

This safety requirement symbol has been adopted by the International Electro-technical Commission, Document 66 (Central Office) 3, paragraph 5.3 which directs that an instrument be so labeled, if, for the correct use of the instrument, it is necessary to refer to the instruction manual. In this case it is recommended that reference be made to the instruction manual when connecting the instrument to the proper power source.

Verify that the right fuse is installed for the power available and that the switch on the rear panel 0.20A and 0.10A, 50-400 Hz, is set to the applicable operating voltage of 115V or 230V.

3.2 OPERATING PROCEDURES

In the following paragraphs, the initial operating procedure is described. as well as operating notes and recommended connection methods.

3.2.1 Initial Operating Procedure

a. Be sure that the serial number of the probe to be used is the same as that of the Voltmeter (Each instrument is calibrated for its particular rf probe.) Use of a probe other than that for which the instrument was calibrated may result in measurement errors.

b. Connect the probe cable to the PROBE jack on the front panel.

c. Check the setting of the power switch on the rear panel to be sure that it is set to the proper position for the line voltage available.

d. Plug the instrument's power cable into a power receptacle and turn the selector switch to mV. Allow a minute for the instrument to warm up.

e. Press the 1 mV range button; the panel meter pointer should rest on the zero reference line. If it does not, use the ZERO control to set the meter to zero. (This adjustment will hold for the other ranges.) The unit is now ready for use (see 3.3.4).

3.3 OPERATING NOTES

While using the Voltmeter is a direct and straightforward process, there are certain precautions and procedures which MUST be observed to obtain satisfactory results.

3.3.1 Overload Limits

The RF Probe supplied with the instrument is overload-protected to 10 volts, ac, and to 400 volts, dc. EXCEEDING THESE LIMITS MAY RESULT IN PERMANENT DAMAGE TO THE PROBE.

The BNC 50 - ohm Adapter should not be subjected to continuous overload of more than 10 volts (dc + rms ac) to avoid excessive heating of the terminating resistor.

Where voltages above these limits are likely to be encountered, the high Z 100:1 Voltage Divider is required. Maximum rating of the Voltage Divider is 1000 volts, dc + peak ac.

3.3.2 Connection for Measurements Below 100 MHz

The RF Probe supplied with the Voltmeter is equipped with a detachable tip and ground lead. For measurements of signals below approximately 100 MHz, this tip provides a convenient means for both signal and ground connection.

3.3.3 Connection for Measurements Above 100 MHz

For frequencies above 100 MHz, the probe tip should NOT be used with the probe. Connection should be made directly to the center contact of the probe with the ground connection kept as short as possible (see Figure 5).

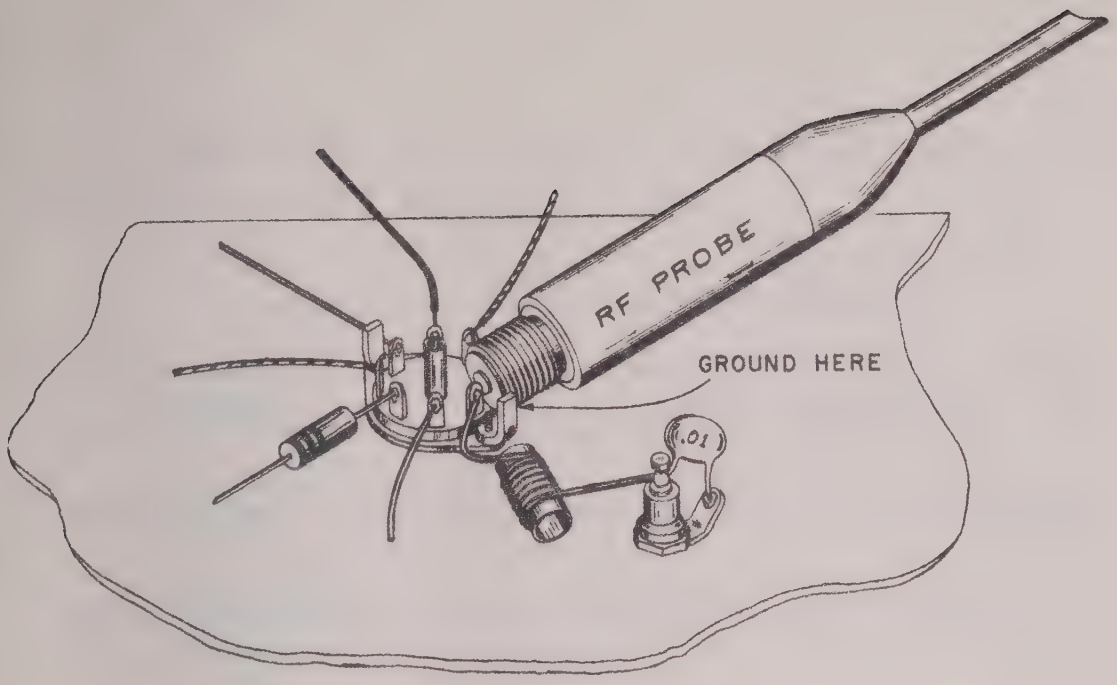


Figure 5. Method for making low-inductance connections to test signal point directly using the RF probe.

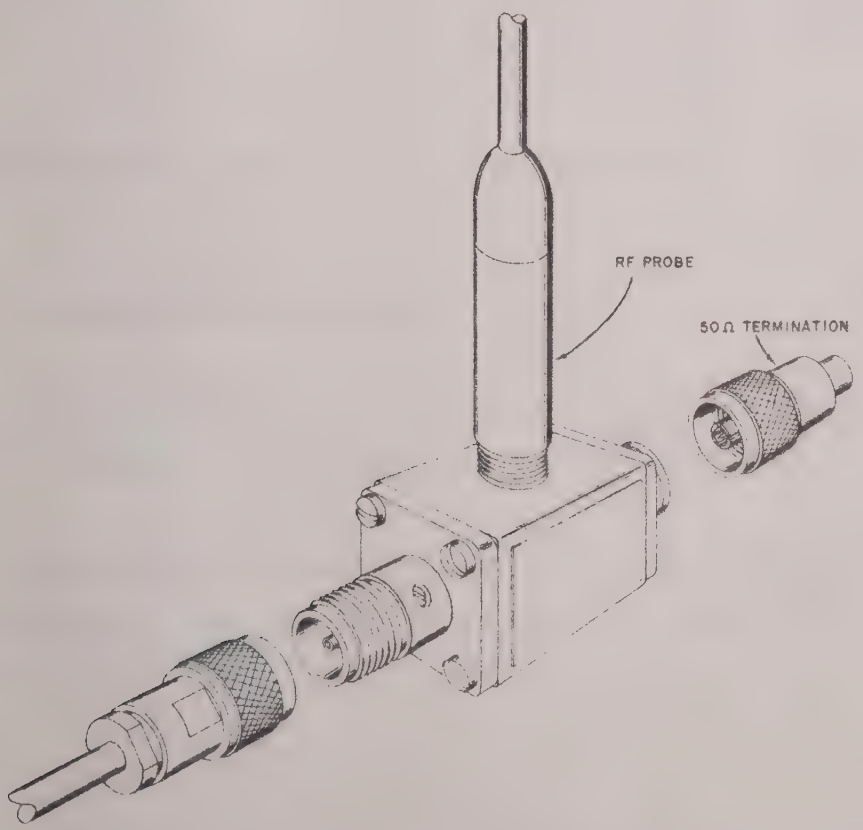


Figure 6. Assembly of Type N Tee Adapter

The connection recommendations outlined in Table 4 should be followed to maintain specified accuracy.

Table 4. Connection Recommendations

FREQUENCY	SIGNAL CONNECTION
Up to 100 MHz	Probe Tip and ground lead (supplied)
100 MHz to 250 MHz	Probe without tip (see Figure 5) (supplied)
250 MHz to 600 MHz	Probe with 50Ω BNC Adapter (supplied)
Beyond 600 MHz	Probe with Type N Tee Adapter and Type N 50Ω Termination (see Figure 6) (optional accessories)

3.3.4 Low-Level Measurement

The RF Voltmeter will provide reliable, reproducible measurements of signal levels as low as 200 microvolts.

Preliminary zero adjustment is essential when using the lowest range scale to achieve the specified accuracy, and is strongly recommended for all ranges up to 30 millivolts.

When the instrument is to be used on the 1 mV range, the following zero adjustment procedure should be followed:

a. Set the FULL SCALE range selector to the 1 mV position.

b. Be sure that no voltage is applied to the probe, and that it is adequately shielded from local fields. This can be done by partially unscrewing the probe cap until the tip just breaks contact with the internal connector, leaving the metal shell engaged with the body threads. Alternately, the probe tip can be removed and the 50-ohm termination mounted in its place.

c. Adjust the ZERO control to bring the meter reading to zero. Noise will cause the reading to fluctuate up to ± 5% of full scale. Adjust the ZERO control so that the reading averages zero.

3.3.5 Over/Under Range Indication

When the rf voltage applied to the probe is approximately 5% above the maximum, or 12% below the minimum, of the range in use, the digital indicator will blank out. In this case, switch to the next appropriate range.

3.3.6 Making the Zero Adjustment

When the instrument is to be used on the 1 mV range, the following zero adjustment procedure applies:

a. Set the FULL SCALE range selector to the 1 mV position.

b. Be sure that no voltage is applied to the probe, and that it is adequately shielded from local fields. (See Para. 3.3.4 and 5.2)

c. Adjust the ZERO control to bring the edge meter reading to the zero reference line. Noise will cause the reading to fluctuate up to ± 5% of full scale. Adjust the ZERO control so that the reading averages to zero.

NOTE: The digital indicator cannot be used to zero-set the instrument as the display automatically blanks out when the applied signal drops below 200 μV -12%.

3.3.7 Signal Overload on 1 mV Range

On the most sensitive (1 mV) range, application of a large ac signal overloads the amplifier and a short time is required for the high-impedance input circuit to discharge. This effect is significant for signals above approximately 100 millivolts. Typically, application of a 1 volt signal will require a recovery time of about thirty seconds before subsequent measurement should be made. It should be noted, however, that such overloads cause no damage to the equipment as long as they are within the limits outlined in paragraph 3.3.1.

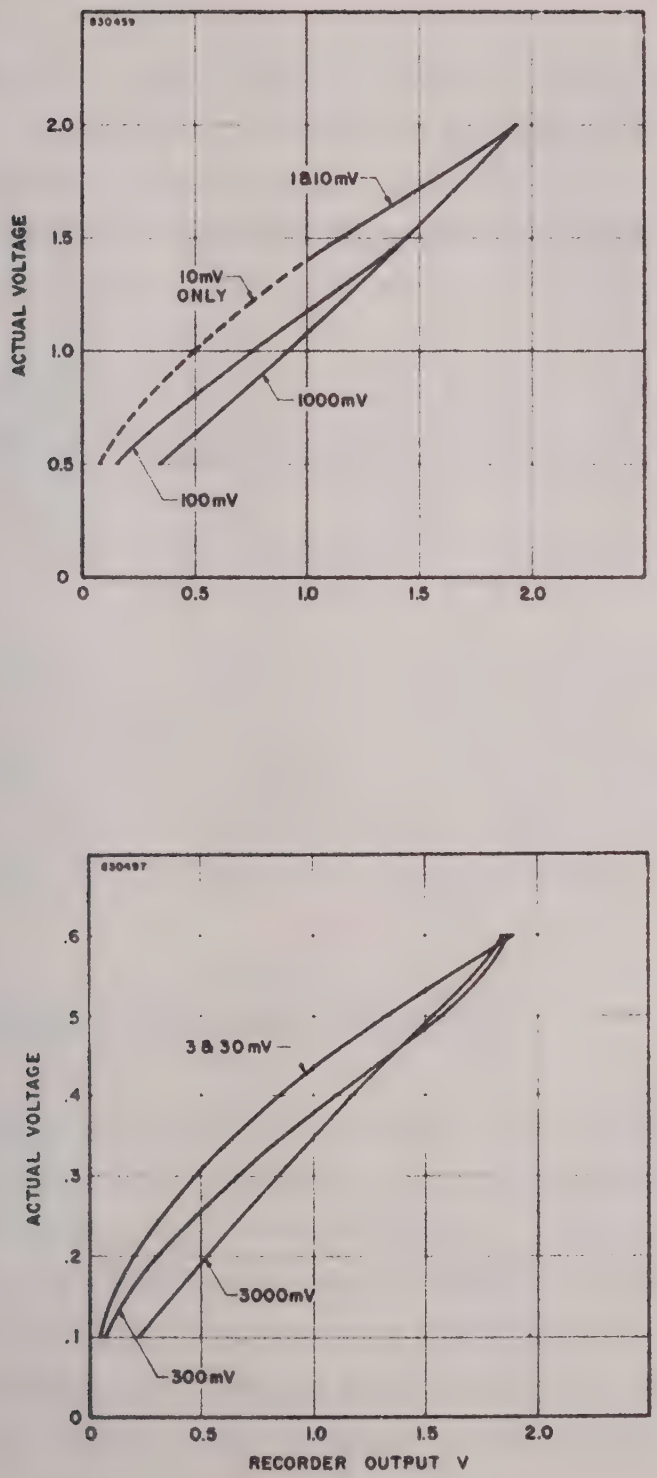
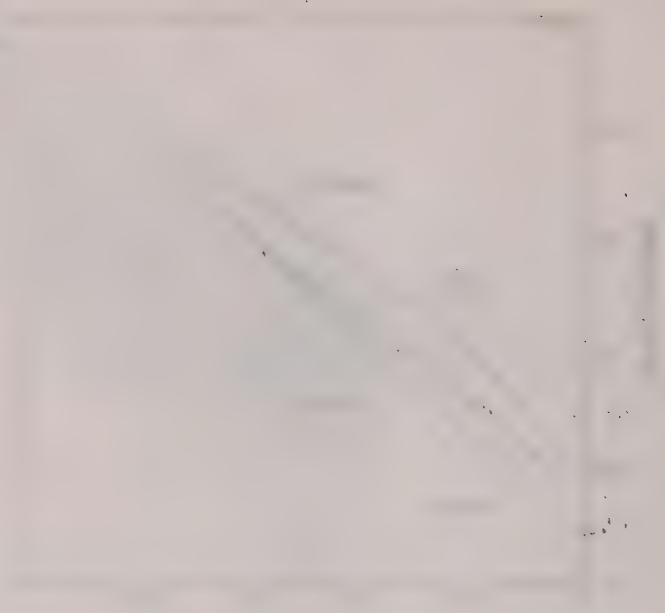


Figure 7. Down-Scale Correction Curves, Recorder Output



3.3.8 Temperature Effects

The accuracy specifications for the Voltmeter apply over temperatures from 50°F to 104°F. Outside of these limits operation of the equipment is possible but appreciable inaccuracies can be expected. However, no permanent change in probe characteristics will result from any reasonable high or low temperature exposure.

It should be noted that inaccuracies of measurement resulting from temperature effects may occur shortly after soldering to the probe tip, or measuring with the probe in the vicinity of heat sources such as resistors, heat sinks, vacuum tubes, and so forth.

When making low-level measurements (below approximately 2 millivolts) it is important to make sure that the probe has attained a uniform temperature throughout its body. A temperature gradient between the inside and outside of the probe can generate a small thermal voltage that may add to the dc output of the detector diodes.

3.3.9 Hum, Noise, and Spurious Pickup

When measuring low-level signals precautions should always be taken to avoid the possibility of errors of measurement resulting from hum, noise, or stray rf pickup. Although all low-frequency hum and noise are attenuated at the input, it is still possible for unwanted high-level signals to cause errors. In some cases it may be necessary to provide extra shielding around the probe connections to reduce stray pickup. Typical sources of spurious

radiation are: induction or dielectric heating units, diathermy machines, local radio transmitters and grid dip meters.

3.4 LINEAR DC OUTPUT

The dc output provided at the rear panel binding posts is a linear fuction (typically, ± 1% f.s.) of the input level, as long as the input signal is greater than 20% of full scale. For inputs less than 20% of full scale the output is NOT linear, but may be corrected by referring to paragraph 3.6 and Figure 7. Polarity of the dc output is positive with respect to the instrument ground, the negative dc output terminal being at ground potential. Output resistance is 9 kΩ.

3.5 LOW-FREQUENCY MEASUREMENTS

The RF Probe supplied provides measurements within the specified accuracy from 10 kHz to 1.2 GHz. For measurements at lower frequencies the low frequency RF Probe is available. It operates over a frequency range from 1 kHz to 250 MHz.

Important Note: After installing the RF Probe, the instrument must be checked for accuracy of calibration, and recalibrated if required (see paragraphs 5.3 and 5.4).

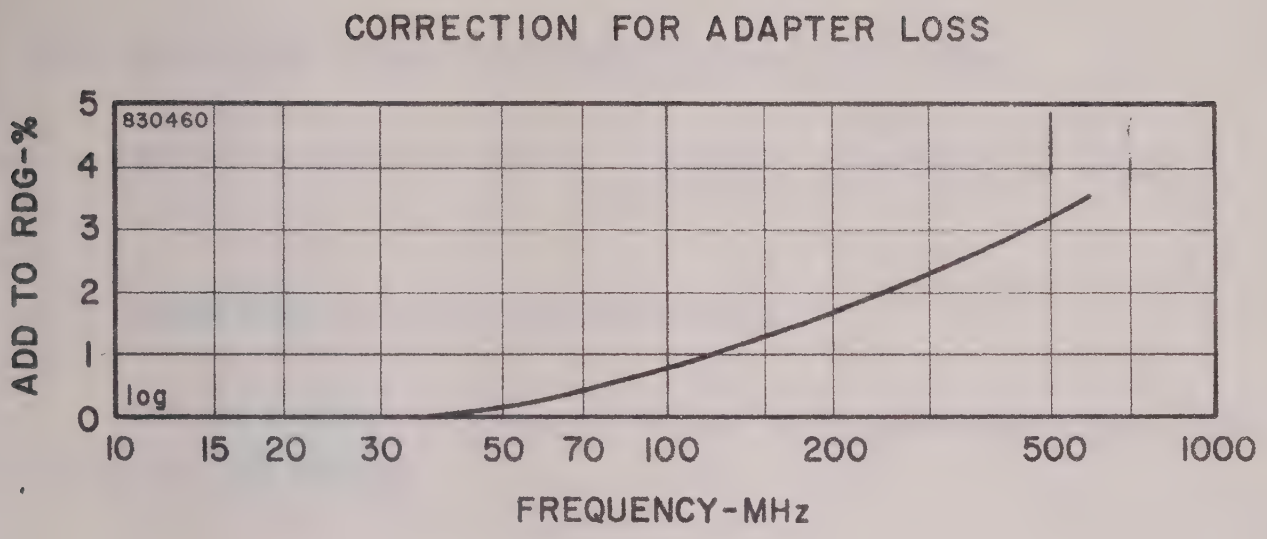


Figure 8A. 50Ω BNC Adapter Correction Curve. (Add to indicated readings.)

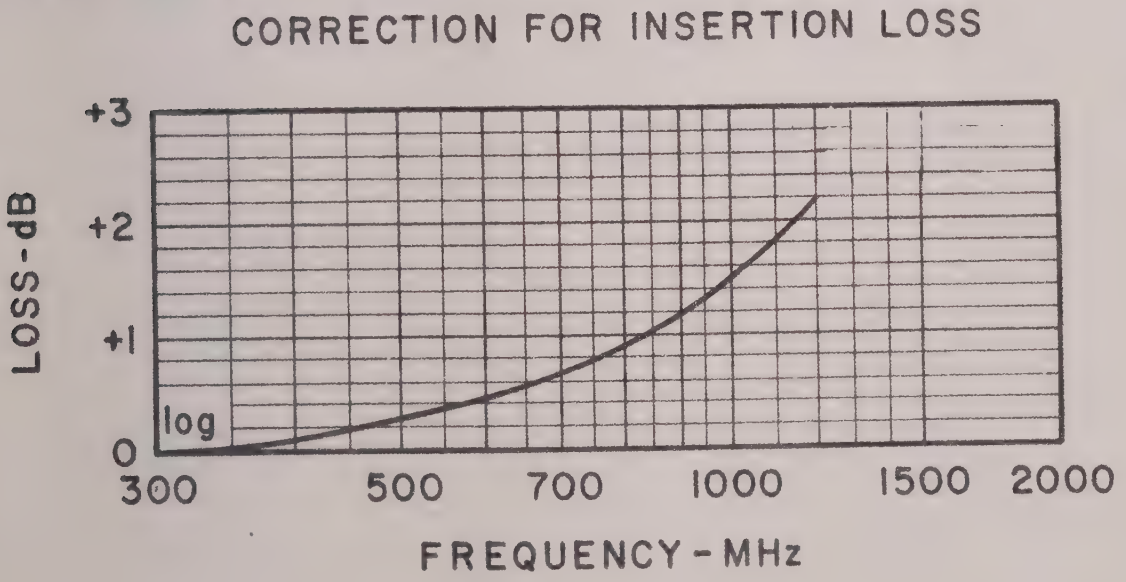


Figure 8B. Type N Tee Adapter Correction Curve. (Input voltage to tee adapter is indicated by voltmeter. Subtract the correction from the indicated value, in dB, to obtain output voltage of tee.)

3.6 CORRECTION CURVES FOR ACTUAL VOLTAGE vs DC OUTPUT

Use the correction curves of Figure 7 to correct dc output.

3.7 CORRECTION CURVE FOR 50Ω BNC ADAPTER

Use the correction curve of Figure 8A to make corrections when using the 50Ω Adapter.

3.8 CORRECTION CURVE FOR 50Ω N TEE ADAPTER

Use the correction curve of Figure 8B to make corrections when using the Type N Tee Adapter.

CHAPTER IV

THEORY

4.1 GENERAL

The operating principles of the Voltmeter are shown in the following block diagram. The essential elements of the instruments are the probe, chopper driver, chopper, attenuator, preamplifier, amplifier, pulse generator, sync detector, shaping amplifier, digital control, analog to digital converter, digital display, panel meter, and power supply.

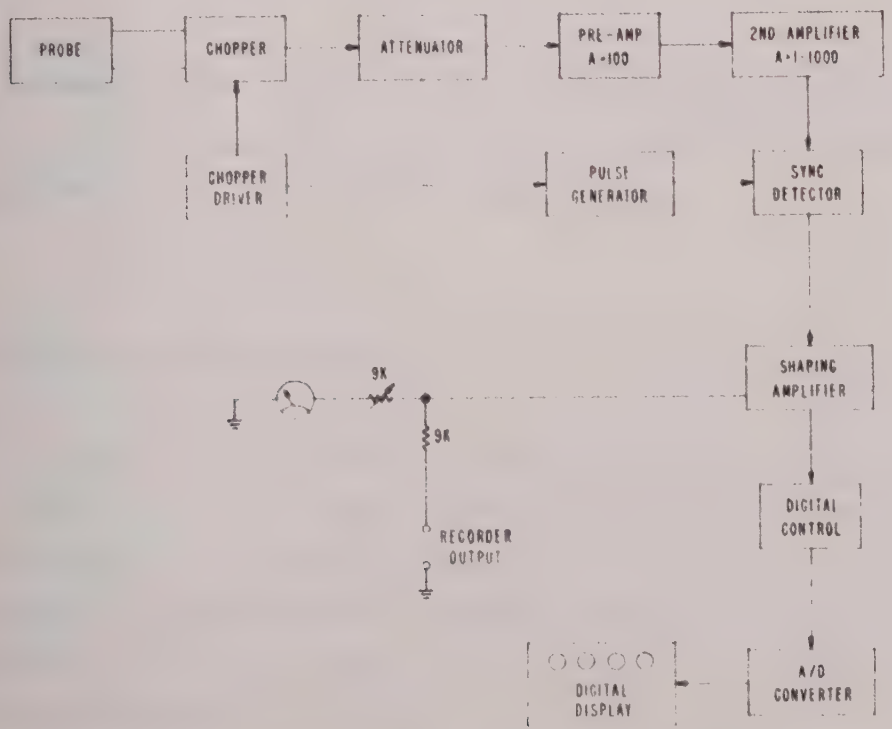


Figure 9. Block Diagram

4.1.1 RF Probe

The RF Probe embodies a full-wave diode detector which rectifies the signal under study to a dc voltage whose level is a function of the input level. While operating in the square-law region (below approximately 30 millivolts) the detector provides true rms response. As the input level increases beyond 30 millivolts, waveform response gradually approaches peak-to-peak, calibrated on the indicator in rms.

In addition to increasing efficiency, use of full-wave rectification in the detector probe permits measurement of signals having highly asymmetrical waveforms without errors stemming from turnover effect.

The diodes used in the RF Probe have been carefully selected for specific characteristics. The user is urged NOT to attempt their replacement with any off-the-shelf types.

4.1.2 Attenuator and Amplifiers

The dc output of the probe is converted to ac by the mechanical chopper. The resultant ac signal is applied to the attenuator and amplifier sections. For each range the output voltage from the 2nd amplifier is approximately 3V peak-to-peak. It is accomplished by ranging both the attenuation and the gain of the 2nd amplifier in the following manner:

RANGE	$\frac{1}{\text{ATTN}}$	GAIN 2nd AMP.
1	1	1000
3	1	100
10	1	10
30	1	1
100	0.15	1
300	0.04	1
1000	0.01	1
3000	0.004	1

The preamplifier has a constant gain of X100, and is designed for very low input noise. Both amplifiers have wide bandwidths and are stabilized by large amounts of negative feedback.

4.1.3 Synchronous Detector

The amplified ac signal from the 2nd amplifier is converted to dc by the synchronous detector. The peak-to-peak amplitude is derived from a shunt-series capacitor storage circuit using JFET switches. The synchronous detector is driven by pulses in the chopper-driver circuit, thus assuring exact synchronization. The characteristics of the detector determine the effective bandwidth of the amplifier-detector combination and allow modification of the bandwidth for different range conditions. The detector also provides conversion without offset, with excellent linearity.

4.1.4 Shaping Amplifier

The conversion of rf to dc in the probe is non-linear, the response being virtually square-law for the lowest ranges and gradually becoming quasi-linear for the 3V range. The shaping amplifier converts the non-linear output of the phase detector to a linear output by using a segmental approximation to the exact correction. The shaping amplifier is actually an operational amplifier so connected that, as the signal increases at its output, its gain is reduced by successively paralleling resistors across the feedback resistors. The number of segments required to adequately linearize the response varies from 6 for the "square-law" ranges down to 2 for the 3V range. The output of the shaping amplifier is +10V which drives the panel meter and is applied to the recorder terminals through a 9 kΩ resistor.

4.1.5 Digital Control

The analog dc signal voltage from the Shaping Amplifier is processed by the Digital Control circuits before being passed on to the Analog/Digital Converter and the Digital Display. The Digital Control section divides the incoming voltage (10 volts full-scale) by factors of 20 or 6.3, depending upon which range group has been selected. It extracts information for the control of range, decimal point position, over- or under-range readings, and polarity indicator.

4.1.6 Analog/Digital Converter

This is a dual-slope type of converter; incoming analog information is changed to digital form and applied to the Digital Display Unit, where the appropriate segments of the LED display are triggered. These show not only numerals, but also over- or under-range indication, polarity, and mV.

4.1.7 Chopper-Driver Circuits

The chopper-driver block provides all of the drive signals required by the instrument. The chopper frequency is obtained by dividing the output of a unijunction oscillator by two. The oscillator also generates the switching pulse for the synchronous detector. Diode gating feeds the pulse to the proper JFET depending upon chopper phase. The chopper frequency is normally adjusted to 94 Hz, but can be changed $\pm$10 Hz to avoid beating with harmonically related ground currents.

4.1.8 Power Supply

The power supply converts the ac input power to regulated +15V and -15V outputs. Each supply is protected by current limiting against accidental short circuits. Both supplies are adjustable to 15.0 $\pm$ 0.1V.

4.1.9 Programming

The instrument is organized around an eight-line ranging system. In each functional subcircuit the switching is accomplished by solid-state devices, generally JFET's, which are actuated by the appropriate range line. The front panel range switch simply connects to the eight range lines to allow range selection. The range lines are buffered by a logic level converter. The instrument may be externally ranged by a logic "0" command on the appropriate range line. (It is recommended that an Amphenol 225-22221-101 connector be used for remote programming connection.)

CHAPTER V

MAINTENANCE

5.1 PERIODIC CALIBRATION

The RF Voltmeter is designed to provide trouble-free operation over extended periods of time. However, as with any precision instrument, the instrument should be checked periodically to verify proper calibration. To make such calibration checks, the following equipment is required:

a. A reliable signal source of 200 kHz to 500 kHz with less than 1% distortion at levels up to 3 volts across 50 ohms.

b. A precision voltmeter such as the Ballantine Model 310A or 314, the Boonton Electronics Model 93A or 93AD, or the Hewlett-Packard Model 400D or 400H or equivalent.

c. A precision dc voltmeter capable of measuring $\pm$15.0V with an accuracy of $\pm$0.1% and input impedance $>$10MΩ.

d. Frequency counter such as Monsanto Model 100A.

5.2 PRECAUTIONS WHEN CHECKING CALIBRATION

When checking the calibration of an instrument having the sensitivity and bandwidth of this RF Voltmeter, it is essential to take precautions against errors resulting from stray pick-up

voltages. (See paragraph 3.3.9.) A well-shielded signal source must be used in conjunction with coaxial connections to both the test meter and the standard reference meter. Even with a well-shielded generator and connections, it is sometimes possible for the reference meter to pick up stray rf signals and feed them into the probe. It is advisable to test for this condition by disconnecting the standard meter and noting any change in level.

5.3 CALIBRATION CHECK

Using the equipment listed in paragraph 5.1, check the calibration of the Voltmeter on each range using a test voltage equal to the full scale value. If the check reveals that recalibration is required, the procedure outlined in paragraph 5.4 should be followed.

5.4 CALIBRATION PROCEDURE

The RF Voltmeter should be calibrated at room temperature (74°F) after a minimum warm-up time of ten minutes.

A calibration outline is provided inside the top cover of the instrument (see Figure 10). The adjustment references listed below are the same as those recorded on the top cover.

Adjustment No. 1. Measure the -15.0V supply voltage at the 15V Test Point located on the Main Amplifier board at C119. Adjust R143 to -15.0 $\pm$ 0.1V.

Adjustment No. 2. Measure the +15.0V supply voltage at the +15V Test Point located on the Main Amplifier board at C118. Adjust R140 for a reading of +15.0 ± 0.1V.

Adjustment No. 3. Set the FULL SCALE range selector to the 1000 mV range, apply 1000 mV input and measure the chopper frequency at Test Point 13, located on the Chopper-Driver board. Adjust R244 for a frequency of 94 ± 1 Hz (106.4 mS). In some cases it may be desirable to offset the chopper frequency to avoid beating with a harmonic of the power line frequency. Any frequency within the adjustment range will not degrade the performance of the instrument.

Adjustment No. 4. Set the FULL SCALE range selector to the 1 mV range and zero the instrument as described in paragraph 3.3.4.

Adjustment No. 5. Set the FULL SCALE range selector to the 30 mV range and adjust R233 for a zero reading at the RECORDER terminals on the back panel.

Adjustment No. 6. Set the FULL SCALE range selector to the 1000 mV range and apply 1000 mV input, adjust R353 for +10.00 V at the RECORDER terminals.

Adjustment No. 7. Set the FULL SCALE range selector to the 1000 mV range and apply 1000 mV input; adjust R1405 for a 1000 mV indication.

Adjustment No. 8. Set the FULL SCALE range selector to the 3000 mV range and apply 3000 mV input; adjust R363 for +9.487 V at the RECORDER terminals.

Adjustment No. 9. Set the FULL SCALE range selector to the 3000 mV range and apply 3000 mV input; adjust R632 for a reading of 3000 mV.

Adjustment No. 10. Set the FULL SCALE range selector to the 1 mV range (zero the instrument as in Adjustment No. 4), apply 1.000 mV input, and adjust R303 for a reading of 1.000 mV.

Adjustment No. 11. Set the FULL SCALE range selector to the 3 mV range (zero as in Adjustment No. 4), apply 3.000 mV input, and adjust R308 for a reading of 3.000 mV.

Adjustment No. 12. Set the FULL SCALE range selector to the 10 mV range (zero as in Adjustment No. 4), apply 10.00 mV, and adjust R318 for a reading of 10.00 mV.

Adjustment No. 13. Set the FULL SCALE range selector to the 30 mV range, apply 30.00 mV input, and adjust R328 for a reading of 30.00 mV.

Adjustment No. 14. Set the FULL SCALE range selector to the 100 mV range, apply 100.00 mV input, and adjust R341 for a reading of 100.0 mV.

Adjustment No. 15. Set the FULL SCALE range selector to the 300 mV range, apply 300.0 mV input, and adjust R347 for an indication of 300.0 mV.

Adjustment No. 16. Set the FULL SCALE range selector to the 300 mV range, apply 224 mV (0 dBm, 50Ω), adjust R644 for 0 dBm indication on the edgemeter.

5.4.1 Special Adjustments

Adjustment A. NOTE: This is considered a factory adjustment; the control should not normally require resetting in ordinary use.

Remove power from the instrument and take the Digital Control board out of its receptacle (J104). Using slivers of tape, carefully mask off pins 1, 2, and 22 on the edge connector of the board. Insert the connector into the receptacle of a Card Extender board and plug the extender into J104. Turn the instrument on and select the 1000 mV range.

Apply a dc voltage of -10.00 $\pm$ 0.01V to the junction of R643 and R636. Adjust R1408 for an indication on the readout of -1000 mV. Remove the card extender and the board, take the tape off the connector pins, and replace the board in J104.

Adjustment B. (This adjustment will be required only if 1C1202 is replaced.)

Adjust C1203 for a 50 mS pulse measured at Pin 8 of 1C1402. If this value cannot be obtained within the range of C1203, try slightly different values of C1202 (up to 200 pF) until the 50 mS pulse is within the range of the trimmer.

5.5 TROUBLE-SHOOTING PROCEDURE

The following trouble-shooting procedures describe the instrument's cover removal, chopper replacement and voltage and resistance tests.

5.5.1 Cover Removal

The cover of the instrument may be removed from the case by removing the screw on the top of the case.

5.5.2 Chopper Replacement

If unsatisfactory operation of the unit develops, a replacement chopper should be tried. If the new chopper does not clear the difficulty, place the original chopper back in the socket. The calibration accuracy should be rechecked after replacement.

5.5.3 Voltage and Resistance Tests

After determining that the trouble cannot be cured by replacement of the chopper (as noted above) it is advisable to make a systematic check of the ac voltage, dc voltage, and resistance. Once the trouble has been found and corrected, the calibration must be rechecked and readjusted as outlined in paragraphs 5.3 and 5.4.

5.5.4 Test Points

Test points, waveforms, and related test voltages are shown in the schematics.

5.5.5 Replacement of RF Probes

The serial number of the Voltmeter matches that of the RF Probe with which it was calibrated at the factory. If it is necessary

to change probes for any reason, the instrument's calibration MUST be rechecked. In most cases, full recalibration (see procedure in paragraph 5.4) will be required. Similarly, if the RF Probe supplied with the instrument is exchanged for a Low Frequency Probe, recalibration will be required. (See paragraph 3.5.)

5.5.6 Probe Tests

The probe assemblies furnished with the Voltmeter can be checked for VSWR and frequency response by following the procedures detailed in the paragraphs below.

Should a probe exhibit out-of-tolerance performance in these tests, the user is urged not to attempt repair himself but to send it back to the factory for repair or adjustment.

A. VSWR Measurement:

1. Test Equipment:

a. Oscillator for desired frequency range:
4.2 - 520 MHz: BEC Model 102A
220 - 920 MHz: GR Type 1362
450 - 1050 MHz: GR Type 1361A

b. Oscillator Power Supply: GR Type 1263-C

c. GR Voltmeter Rectifier Type 874-VR

d. Slotted Line: GR Type 900 LB

e. GR Detector Type 1241

f. Tee Adapter: BEC Model 91-14A

g. 50-ohm Termination: BEC Model 91-15A

2. Test Procedure:

a. Assemble the equipment as shown in the block diagram following this section.

b. Set the oscillator to the desired test frequency and adjust the output level for a reading of approximately half-scale on the 30 mV voltmeter range.

c. Adjust the carriage of the slotted line to a point of minimum voltage on the meter, and record the value.

d. Adjust the carriage to a maximum-voltage point and record this value.

e. The VSWR is equal to the ratio of the two voltages recorded in steps c and d.

f. The measurement may be repeated at other frequencies as required.

B. Frequency Response

1. Test Equipment:

a. Oscillator for desired frequency range:
4.2 - 520 MHz: BEC Model 102A
220 - 920 MHz: GR Type 1362
450 - 1050 MHz: GR Type 1361A

b. Power Supply: GR Type 1263-C

c. GR Voltmeter Rectifier Type 874-VR

d. 1.0 GHz Low-Pass Filter: GR Type 874-F100L

e. 20 dB 50-Ω Pad: GR Type 874-G20

f. BEC Model 91-14A Tee Adapter

g. BEC Model 91-15A 50-ohm termination

h. RF Millivoltmeter

2. Test Procedure:

a. Assemble the equipment as shown in the block diagram following this section.

b. Set the oscillator to the low-frequency end of its tuning range and the voltmeter to the 100 mV

range. Adjust the oscillator power to give a reading of 0 dBm on the meter.

c. Adjust the oscillator to successively higher frequencies as convenient, recording the voltmeter reading at each frequency. The results may be plotted on a graph, if desired.

Figure 10.

BLOCK DIAGRAM OF RF PROBE VSWR TEST

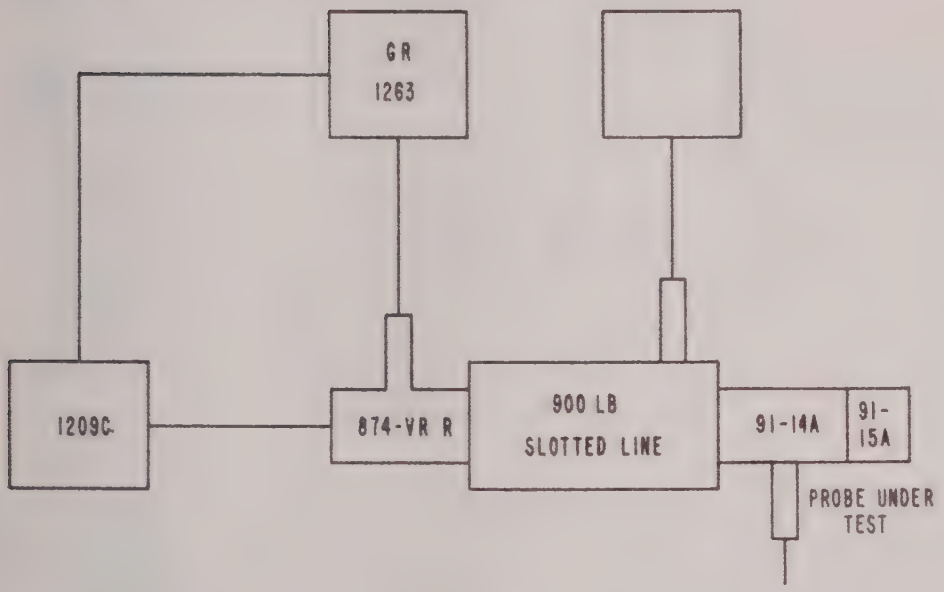
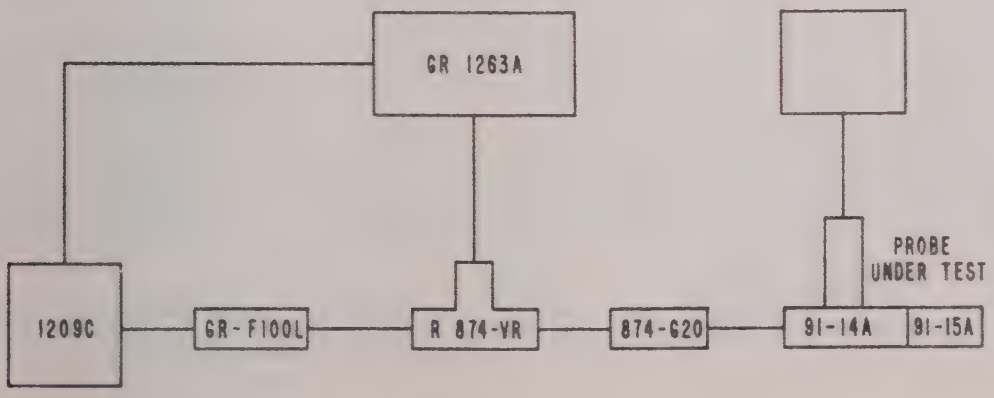
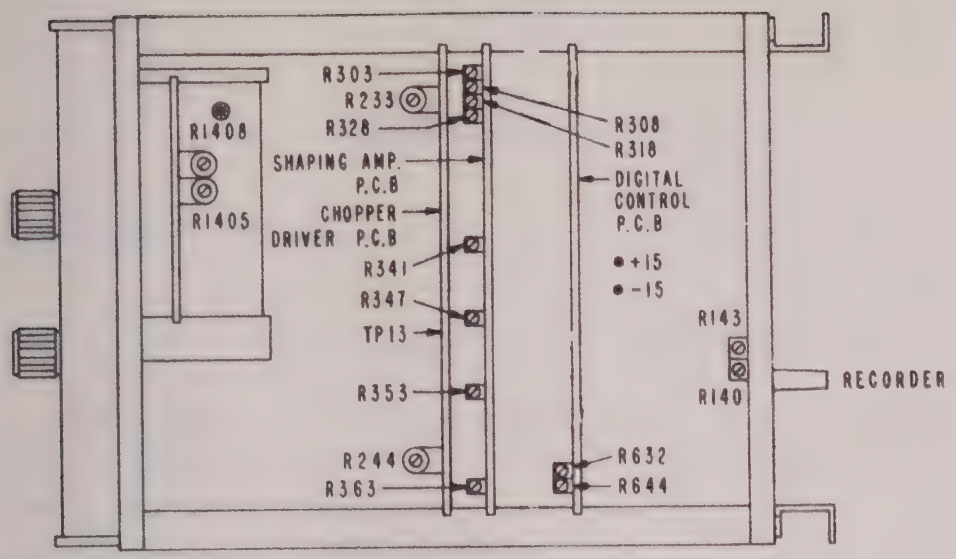


Figure 11.

BLOCK DIAGRAM OF RF PROBE RESPONSE TEST





⊛ FACTORY ADJUSTMENT: REFER TO MANUAL
• TEST POINT
† REPEAT STEP #4
✱ INSTRUMENTS WITH dB OPTION ONLY

ADJ NO	CONT	FUNCTION	RANGE	INPUT ±0.2%	ADJUST
1	R143	-15V ADJ	—	0	-15.0V ±0.1V AT -15V TP
2	R140	+15V ADJ	—	0	+15.0V ±0.1V AT +15V TP
3	R244	CHOPPER FREQUENCY	1000 mV	1000 mV	94 ±1Hz AT TP 13
4	R401	FRONT PANEL ZERO	1 mV	0	AVERAGE ZERO INDICATION AT RECORDER TERMINALS
5	R233	DC ZERO	30 mV	0	ZERO INDICATION AT RECORDER TERMINALS
6	R353	RANGE ADJ	1000 mV	1000 mV	+10.00V AT RECORDER TERMINALS DC VOLTMETER INPUT >10 M OHMS
7	R1405	+DPM FS ADJ	1000 mV	1000 mV	1000 mV INDICATION
8	R363	RANGE ADJ	3000 mV	3000 mV	+9.487V AT RECORDER TERMINALS DC VOLTMETER INPUT >10 M OHMS
9	R632	3 DIVIDER	3000 mV	3000 mV	3000 mV INDICATION
10†	R303	RANGE ADJ	1 mV	1 mV	1.000 mV INDICATION
11†	R308	RANGE ADJ	3 mV	3 mV	3.000 mV INDICATION
12†	R318	RANGE ADJ	10 mV	10 mV	10.00 mV INDICATION
13	R328	RANGE ADJ	30 mV	30 mV	30.00 mV INDICATION
14	R341	RANGE ADJ	100 mV	100 mV	100.0 mV INDICATION
15	R347	RANGE ADJ	300 mV	300 mV	300.0 mV INDICATION
16	R644	EDGEMETER ADJ	300 mV 300 mV 1000 mV	224 mV 274 mV 1000 mV	ZERO dBm INDICATION (50 OHMS REF) ZERO dBm INDICATION (75 OHMS REF) ZERO dBV INDICATION

Figure 12. Calibration Instructions

CHAPTER VI

INTERFACE INFORMATION

6.1 PROGRAMMING INPUTS

Pin No.	Function	Comment	Command	Unit Loading
7	Man. disable	Disables front panel range selection	0	0.1
16	1mV range	Selects range provided	0	0.1
15	3mV "	manual disable has also	0	0.1
14	10mV "	been selected, and auto-	0	0.1
13	30mV "	range has not been se-	0	0.1
12	100mV "	lected; selecting more	0	0.1
11	300mV "	than one range will re-	0	0.1
10	1 V "	sult in incorrect indica-	0	0.1
9	3 V "	tions. Range lines must be deselected for manual.	0	0.1
X	Encode hold	Holds display	0	0.2
V	Encode trigger	Starts encode cycle	(See 6.3.1)	0.1

6.1.1 Input Characteristics

TTL Series	Logic Level	Voltage Level	Current per Unit Load
Standard	0	_ 0.7 V	-1.6 mA*
Power 54/74	1	2.4 to 5.25 V	40 μA

*The -current indicates current out of the input (external command device must sink this current). A standard power (Series 54/74) TTL output will sink and source 10 unit loads.

6.1.2 Input Pull-Up

All input terminals have internal pull-up. The current sourced by this pull-up when the input is brought to a logic level 0 is included in the loading shown in the "Unit Loading" column of the chart in 6.1.

6.1.3 Triggering

To trigger an encode cycle, the trigger line must be transferred from logic "1" to logic "0". Limits for trigger pulse characteristics are shown in 6.3.1.

6.2 DATA OUTPUTS

Pin No.	Function	Comment	True Logic Level	54/74 Unit Load
4	DC Analog	10 V for full scale of "1" ranges; 9.5 V on "3" ranges.	n/a	n/a
21	Overrange	Indicates that instrument range should be increased.	0	1
20	Und. Range	Indicates that instrument range should be decreased.	0	1
W	Encode complete	Indicates completion of encode cycle; data output may be read.	1	1
17 18 19	4 range 2 code 1	Indicates range selected in binary code; 0 = 1 mV range, 7 = 3000 mV range.	1	1
F E D C	8 BCD 4 enc. 2 data 1	Data in serial form, continuously scanned, left (MSD) to right, 500 µs/digit, 2 ms scan.	1 1 1 1	1 1 1 1
H J K L	4 3 Digit 2 select 1	Indicates digit to which BCD data applies; 4 + MSD (left-most).	1 1 1 1	1 1 1 1

6.2.1 Output Characteristics

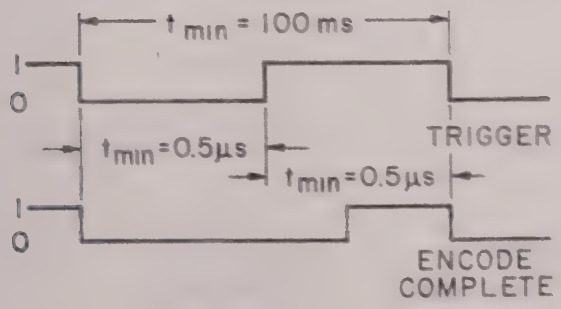
TTL Series	Logic Level	Voltage Level	Current per Unit Load
Standard	0	_ 0.7 V	1.6 mA*
Power 54/74	1	2.4 to 5.25 V	-40 µA

6.2.2 Analog Output

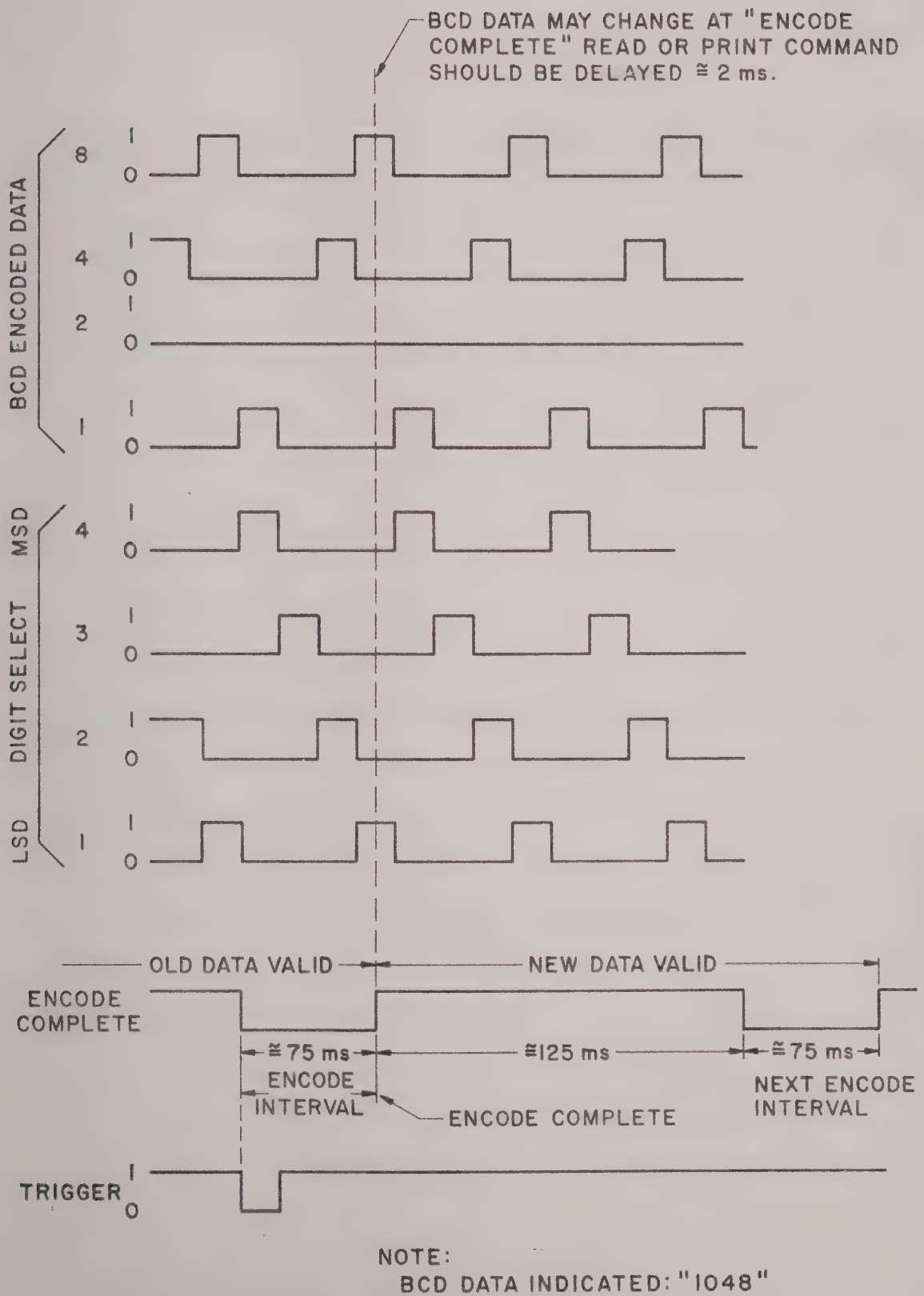
Source resistance is = 9 kΩ.

6.3 WAVEFORMS

6.3.1 Encode Trigger



6.3.2 Data Output Timing



NOTE:
BCD DATA INDICATED: "1048"

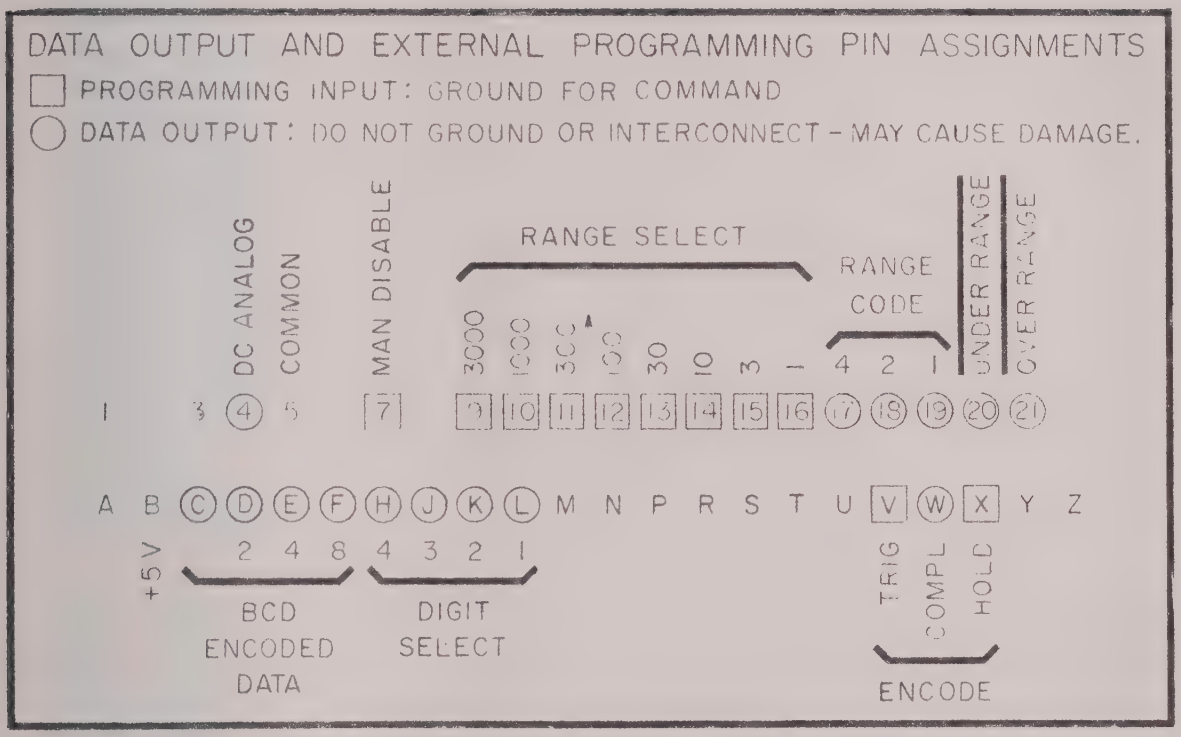


Figure 13. External Connections

TABLE OF REPLACEABLE PARTS

Reference		Description	Part No.
		AMPLIFIER PC BOARD	
C101	Capacitor, PE	100 nF 10% 200 V	234005
C102	Capacitor, Elec.	10 µF 20% 20 V	283205
C103	Capacitor, Mica	100 pF 5% 500 V	200001
C104	Capacitor, Elec.	10 µF 20% 20 V	283205
C105	Capacitor, Elec.	33 µF 20% 15 V	283206
C106	Capacitor, Elec.	10 µF 20% 20 V	283205
C107	Capacitor, Met.	1.0 µF 20% 100 V	236007
C108	Capacitor, Elec.	1.0 µF 20% 35 V	283199
C109	Capacitor, Elec.	50 µF 25 V	283159
C110	Capacitor, Elec.	50 µF 25 V	283159
C111	Capacitor, PE	100 nF 10% 200 V	234005
C112	Capacitor, Elec.	250 µF 40 V	283207
C113	Capacitor, Elec.	250 µF 40 V	283207
C114	Capacitor, Elec.	1000 µF +150/-10% 15 V	283221
C115	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C116	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C117	Capacitor, Elec.	10 µF 20% 20 V	283205
C118	Capacitor, Elec.	100 µF 25 V	283105
C119	Capacitor, Elec.	100 µF 25 V	283105
CR101	Diode, Sil.	FDH-300	530052
CR102	Diode, Sil.	1N914	530058
CR103	Diode, Sil.	1N914	530058
CR104	Diode, Zener	1N5243B (13 V 5%)	530101
CR105	Diode, Zener	1N5235B (6.8 V 5%)	530089
CR106 through CR110	Diode, Sil.	1N914	530058
CR111	Bridge, Rectifier	KBP-02	532013
CR112	Bridge, Rectifier	KBP-02	532013
CR113	Bridge, Rectifier	KBP-02	532013
CR114 through CR125	Diode, Sil.	1N914	530058
IC101	Voltage Regulator	µA7805UC	535011
IC102	Voltage Regulator	µA7805UC	535011
IC103	Voltage Regulator	µA7805UC	535011
IC104	Voltage Regulator	LM723CN	535037
IC105	Voltage Regulator	LM723CN	535037
IC106	Integrated Circuit	SN74L00N	534002
J101	Card Edge Connector	22 Position	479231
J102	Card Edge Connector	22 Position	479231
J103	Card Edge Connector	22 Position	479231
J104	Card Edge Connector	44 Position	479254

Reference	Description		Part No.
	AMPLIFIER PC BOARD (CONTINUED)		
Q101	Transistor, FET	2N5949	528019
Q102	Transistor, FET	2N5949	528019
Q103	Transistor, FET	3N161	528132
Q104	Transistor, FET	2N5949	528019
Q105	Transistor, FET	TIS58	528038
Q106	Transistor, FET	HDGP1001	528057
Q107	Transistor, FET	3N161	528132
Q108	Transistor, FET	2N5949	528019
Q109	Transistor, FET	Selected	528044
Q110	Transistor, NPN	2N5088	528047
Q111	Transistor, PNP	2N5087	528042
Q112	Transistor, NPN-PNP	D39C2	528048
Q113	Transistor, PNP	2N5087	528042
Q114	Transistor, NPN	2N5088	528047
Q115	Transistor, FET	TIS58	528038
Q116	Transistor, FET	TIS58	528038
Q117	Transistor, FET	TIS58	528038
Q118	Transistor, FET	2N5949	528019
Q119	Transistor, FET	2N5949	528019
Q120	Transistor, FET	2N5949	528019
Q121	Transistor, NPN-PNP	D39C2	528048
Q122 through Q132	Transistor, PNP	MPS6516	528037
R101	Resistor, Comp.	1 MΩ 5%	344600
R102	Resistor, Comp.	6.2 kΩ 5%	343376
R103	Resistor, Comp.	6.2 kΩ 5%	343376
R104	Resistor, MF	5.62 MΩ 1% 1/4 W	325397
R105	Resistor, MF	24.3 kΩ 1%	341437
R106	Resistor, MF	80.6 kΩ 1%	341487
R107	Resistor, MF	374 kΩ 1%	341555
R108	Resistor, MF	294 kΩ 1%	341545
R109	Resistor, MF	1.0 MΩ 1%	342600
R110	Resistor, Comp.	91 kΩ 5%	344492
R111	Resistor, Comp.	47 kΩ 5%	344465
R112	Resistor, Comp.	33 kΩ 5%	344450
R113	Resistor, Comp.	300 kΩ 5%	344546
R114	Resistor, MF	169 Ω 1%	341222
R115	Resistor, Comp.	10 kΩ 5%	344400
R116	Resistor, Comp.	10 kΩ 5%	344400
R117	Resistor, Comp.	33 kΩ 5%	344450
R118	Resistor, MF	15.0 kΩ 1%	341417
R119	Resistor, Comp.	15 kΩ 5%	344417
R120	Resistor, Comp.	3.6 kΩ 5%	344353
R121	Resistor, Comp.	3 kΩ 5%	344346
R122	Resistor, Comp.	1 MΩ 5%	344600
R123	Resistor, Comp.	2.7 kΩ 5%	344341
R124	Resistor, Comp.	5.6 kΩ 5%	344372
R125	Resistor, Comp.	5.6 kΩ 5%	344372

Reference	Description		Part No.
	AMPLIFIER PC BOARD (CONTINUED)		
R126	Resistor, Comp.	1 kΩ 5%	344300
R127	Resistor, Comp.	5.1 kΩ 5%	344368
R128	Resistor, Comp.	15 kΩ 5%	344417
R129	Resistor, Comp.	1 kΩ 5%	344300
R130	Resistor, Comp.	10 kΩ 5%	344400
R131	Resistor, MF	30.1 kΩ 1%	341446
R132	Resistor, MF	3.01 kΩ 1%	341346
R133	Resistor, MF	301 Ω 1%	341246
R134	Resistor, MF	33.2 Ω 1%	341150
R135	Resistor, Comp.	1 MΩ 5%	344600
R136	Resistor, Comp.	1 kΩ 5%	343300
R137	Resistor, Comp.	1 kΩ 5%	343300
R138	Resistor, Comp.	15 kΩ 5%	344417
R139	Resistor, MF	3.32 kΩ 1%	341350
R140	Resistor, Var.	1 kΩ ±10% 0.5 W	311316
R141	Resistor, MF	3.01 kΩ 1%	341346
R142	Resistor, MF	3.32 kΩ 1%	341350
R143	Resistor, Var.	1 kΩ ±10% 0.5 W	311316
R144	Resistor, MF	3.01 kΩ 1%	341346
R145	Resistor, MF	9.09 kΩ 1%	341392
R146	Resistor, Comp.	160 kΩ 5%	343520
R147	Resistor, Comp.	39 kΩ 5%	343457
R148	Resistor, Comp.	100 kΩ 5%	343500
R149	Resistor, Comp.	160 kΩ 5%	343520
R150	Resistor, Comp.	39 kΩ 5%	343457
R151	Resistor, Comp.	100 kΩ 5%	343500
R152	Resistor, Comp.	160 kΩ 5%	343520
R153	Resistor, Comp.	39 kΩ 5%	343457
R154	Resistor, Comp.	100 kΩ 5%	343500
R155	Resistor, Comp.	160 kΩ 5%	343520
R156	Resistor, Comp.	39 kΩ 5%	343457
R157	Resistor, Comp.	100 kΩ 5%	343500
R158	Resistor, Comp.	160 kΩ 5%	343520
R159	Resistor, Comp.	39 kΩ 5%	343457
R160	Resistor, Comp.	100 kΩ 5%	343500
R161	Resistor, Comp.	160 kΩ 5%	343520
R162	Resistor, Comp.	39 kΩ 5%	343457
R163	Resistor, Comp.	100 kΩ 5%	343500
R164	Resistor, Comp.	160 kΩ 5%	343520
R165	Resistor, Comp.	39 kΩ 5%	343457
R166	Resistor, Comp.	100 kΩ 5%	343500
R167	Resistor, Comp.	160 kΩ 5%	343520
R168	Resistor, Comp.	39 kΩ 5%	343457
R169	Resistor, Comp.	100 kΩ 5%	343500
R170	Resistor, Comp.	160 kΩ 5%	343520
R171	Resistor, Comp.	39 kΩ 5%	343457
R172	Resistor, Comp.	100 kΩ 5%	343500
R173	Resistor, Comp.	160 kΩ 5%	343520
R174	Resistor, Comp.	39 kΩ 5%	343457
R175	Resistor, Comp.	100 kΩ 5%	343500

Reference	Description		Part No.
		AMPLIFIER PC BOARD (CONTINUED)	
R176	Resistor, Comp.	160 kΩ 5%	343520
R177	Resistor, Comp.	39 kΩ 5%	343457
R178	Resistor, Comp.	100 kΩ 5%	343500
R179	Not Used		
R180	Not Used		
R181	Resistor, Comp.	1.8 kΩ 5%	343325
R182	Resistor, Comp.	1.8 kΩ 5%	343325
R183	Resistor, Comp.	4.7 kΩ 5%	343365
		CHOPPER DRIVER PC BOARD	
A201	Op. Amp.	LM310H	535005
C201	Capacitor, PC	100 nF 10% 50 V	234046
C202	Capacitor, PE	6.8 nF 10% 200 V	234044
C203	Capacitor, Mica	100 pF 5% 500 V	200001
C204	Capacitor, Mica	100 pF 5% 500 V	200001
C205	Capacitor, PE	22 nF 10% 200 V	230101
C206	Capacitor, PC	100 nF 10% 50 V	234046
C207	Capacitor, Mica	100 pF 5% 500 V	200001
C208	Capacitor, PC	100 nF 10% 50 V	234046
C209	Capacitor, Cer.	10 nF 100 V	224119
C210	Capacitor, Cer.	10 nF 100 V	224119
C211	Capacitor, PE	22 nF 10% 200 V	230101
C212	Capacitor, PC	470 nF 10% 80 V	234128
C213	Capacitor, Mica	100 pF 5% 500 V	200001
C214	Capacitor, Elec.	50 µF 25 V	283159
C215	Capacitor, Elec.	50 µF 25 V	283159
C216	Capacitor, Elec.	50 µF 25 V	283159
C217	Capacitor, Elec.	150 µF -10%/+75% 15 V	283307
CR201 through CR218	Diode, Sil.	1N914	530058
CR219	Diode, Sil.	FDH-300	530052
Q201	Transistor, Unij.	2N4871	528051
Q202	Transistor, NPN	MPS-A20	528043
Q203	Transistor, PNP	2N5087	528042
Q204	Transistor, NPN	2N5088	528047
Q205	Transistor, NPN	MPS-A20	528043
Q206	Transistor, FET	MPS-A12	528052
Q207	Transistor, NPN	MPS-A20	528043
Q208	Transistor, FET	Selected	528093
Q209	Transistor, NPN	MPS-A20	528043
Q210	Transistor, FET	Selected	528093
Q211	Transistor, FET	2N5949	528019
Q212	Transistor, NPN	MPS-A20	528043
Q213	Transistor, NPN	2N5308	528050
Q214	Transistor, NPN	2N5308	528050

Reference	Description		Part No.
	CHOPPER DRIVER PC BOARD (CONTINUED)		
R201	Resistor, Comp.	10 kΩ 5%	344400
R202	Resistor, Comp.	22 kΩ 5%	344433
R203	Resistor, Comp.	10 kΩ 5%	344400
R204	Resistor, Comp.	100 Ω 5%	344200
R205	Resistor, Comp.	33 kΩ 5%	344450
R206	Resistor, Comp.	10 kΩ 5%	344400
R207	Resistor, Comp.	100 kΩ 5%	344500
R208	Resistor, Comp.	3.3 kΩ 5%	344350
R209	Resistor, Comp.	4.7 kΩ 5%	344365
R210	Resistor, Comp.	10 kΩ 5%	344400
R211	Resistor, Comp.	150 kΩ 5%	344517
R212	Resistor, Comp.	10 kΩ 5%	344400
R213	Resistor, Comp.	10 kΩ 5%	344400
R214	Resistor, Comp.	22 kΩ 5%	344433
R215	Resistor, Comp.	10 kΩ 5%	344400
R216	Resistor, Comp.	270 kΩ 5%	344541
R217	Resistor, Comp.	240 kΩ 5%	344537
R218	Resistor, Comp.	10 kΩ 5%	344400
R219	Resistor, Comp.	15 kΩ 5%	
R220	Resistor, Comp.	10 kΩ 5%	344400
R221	Resistor, Comp.	10 kΩ 5%	344400
R222	Resistor, Comp.	10 kΩ 5%	344400
R223	Resistor, Comp.	4.7 kΩ 5%	344365
R224	Resistor, Comp.	12 kΩ 5%	344408
R225	Resistor, Comp.	100 kΩ 5%	344500
R226	Resistor, Comp.	100 kΩ 5%	344500
R227	Resistor, Comp.	15 kΩ 5%	344417
R228	Resistor, Comp.	10 kΩ 5%	344400
R229	Resistor, Comp.	100 kΩ 5%	344500
R230	Resistor, Comp.	12 kΩ 5%	344408
R231	Resistor, Comp.	4.7 kΩ 5%	344365
R232	Resistor, Comp.	100 kΩ 5%	344500
R233	Resistor, Var.	2 kΩ 20% 1/2 W	311285
R234	Resistor, Comp.	100 kΩ 5%	344500
R235	Resistor, Comp.	100 kΩ 5%	344500
R236	Resistor, Comp.	27 kΩ 5%	344441
R237	Resistor, Comp.	100 kΩ 5%	344500
R238	Resistor, Comp.	100 kΩ 5%	344500
R239	Resistor, Comp.	1.6 kΩ 5%	344320
R240	Resistor, Comp.	300 Ω 5%	344246
R241	Resistor, Comp.	200 Ω 5% 1 W	302082
R242	Resistor, Comp.	150 kΩ 5%	344517
R243	Resistor, Comp.	510 kΩ 5%	344568
R244	Resistor, Var.	50 kΩ 20% 1/2 W	311282
R245	Resistor, Comp.	47 Ω 5%	344155
	SHAPING AMPLIFIER PC BOARD		
A301	Op. Amp.	LM301AN	535012

Reference	Description		Part No.
	SHAPING AMPLIFIER PC BOARD (CONTINUED)		
C301	Capacitor, Cer.	10 nF 100 V	224119
C302	Capacitor, Mica	33 pF 5% 500 V	200049
C303	Capacitor, Cer.	10 nF 100 V	224119
CR301 through CR308	Diode, Sil.	1N914	530058
Q301	Transistor, FET	2N5949	528019
Q302	Transistor, FET	2N5949	528019
Q303	Transistor, FET	2N5949	528019
Q304	Transistor, PNP	2N5087	528042
Q305	Transistor, FET	2N5949	528019
Q306	Transistor, PNP	2N5087	528042
Q307	Transistor, FET	2N5949	528019
Q308	Transistor, PNP	2N5087	528042
Q309	Transistor, FET	2N5949	528019
Q310	Transistor, PNP	2N5087	528042
Q311	Transistor, FET	2N5949	528019
Q312	Transistor, PNP	2N5087	528042
Q313	Transistor, FET	2N5949	528019
Q314	Transistor, FET	2N5949	528019
Q315	Transistor, FET	2N5949	528019
Q316	Transistor, FET	2N5949	528019
Q317	Transistor, PNP	2N5087	528042
Q318	Transistor, NPN	2N5088	528047
Q319	Transistor, PNP	2N5087	528042
Q320	Transistor, NPN	2N5088	528047
Q321	Transistor, PNP	2N5087	528042
Q322	Transistor, PNP	2N5087	528042
Q323	Transistor, FET	2N5949	528019
Q324	Transistor, FET	2N5949	528019
Q325	Transistor, PNP	2N5087	528042
Q326	Transistor, FET	2N5949	528019
Q327	Transistor, PNP	2N5087	528042
Q328	Transistor, FET	2N5949	528019
Q329	Transistor, PNP	2N5087	528042
Q330	Transistor, FET	2N5949	528019
Q331	Transistor, FET	2N5949	528019
Q332	Transistor, PNP	2N5087	528042
Q333	Transistor, PNP	2N5087	528042
Q334	Transistor, PNP	2N5087	528042
Q335	Transistor, FET	2N5949	528019
Q336	Transistor, FET	2N5949	528019
Q337	Transistor, PNP	2N5087	528042
Q338	Transistor, PNP	2N5087	528042
Q339	Transistor, PNP	2N5087	528042
R301	Resistor, Comp.	130 Ω 5%	344211

Reference	Description		Part No.
	SHAPING AMPLIFIER PC BOARD (CONTINUED)		
R302	Resistor, Comp.	4.7 MΩ 5%	344665
R303	Resistor, Var.	1 kΩ 10% 1 W	311256
R304	Resistor, MF	10 kΩ 1%	341400
R305	Resistor, Comp.	4.7 MΩ 5%	344665
R306	Resistor, MF	51.1 kΩ 1%	341468
R307	Resistor, MF	2.49 kΩ 1%	341338
R308	Resistor, Var.	1 kΩ 10% 1 W	311256
R309	Resistor, MF	28.7 kΩ 1%	341444
R310	Resistor, MF	200 kΩ 1%	341529
R311	Resistor, MF	100 kΩ 1%	341500
R312	Resistor, MF	40.2 kΩ 1%	341458
R313	Resistor, MF	191 kΩ 1%	341527
R314	Resistor, MF	11 kΩ 1%	341404
R315	Resistor, Comp.	4.7 MΩ 5%	344665
R316	Resistor, MF	29.4 kΩ 1%	341445
R317	Resistor, MF	95.3 kΩ 1%	341494
R318	Resistor, Var.	1 kΩ 10% 1 W	311256
R319	Resistor, MF	28.0 kΩ 1%	341443
R320	Resistor, MF	64.9 kΩ 1%	341478
R321	Resistor, MF	1.00 MΩ 1%	342600
R322	Resistor, MF	26.1 kΩ 1%	341440
R323	Resistor, MF	46.4 kΩ 1%	341464
R324	Resistor, MF	10 kΩ 1%	341400
R325	Resistor, Comp.	4.7 MΩ 5%	344665
R326	Resistor, MF	45.3 kΩ 1%	341463
R327	Resistor, MF	2.49 kΩ 1%	341338
R328	Resistor, Var.	1 kΩ 10% 1 W	311256
R329	Resistor, Comp.	270 kΩ 5%	344541
R330	Resistor, MF	21.5 kΩ 1%	341432
R331	Resistor, MF	237 kΩ 1%	341536
R332	Resistor, Comp.	18 kΩ 5%	344425
R333	Resistor, MF	26.1 kΩ 1%	341440
R334	Resistor, MF	154 kΩ 1%	341518
R335	Resistor, Comp.	47 kΩ 5%	344465
R336	Resistor, MF	54.9 kΩ 1%	341471
R337	Resistor, MF	191 kΩ 1%	341527
R338	Resistor, Comp.	4.7 MΩ 5%	344665
R339	Resistor, MF	82.5 kΩ 1%	341488
R340	Resistor, MF	178 kΩ 1%	341524
R341	Resistor, Var.	1 kΩ 10% 1 W	311256
R342	Resistor, MF	17.8 kΩ 1%	341424
R343	Resistor, MF	2.74 kΩ 1%	341342
R344	Resistor, Comp.	4.7 MΩ 5%	344665
R345	Resistor, MF	24.3 kΩ 1%	341437
R346	Resistor, MF	232 kΩ 1%	341535
R347	Resistor, Var.	1 kΩ 10% 1 W	311256
R348	Resistor, MF	95.3 kΩ 1%	341494
R349	Resistor, MF	453 kΩ 1%	341563
R350	Resistor, Comp.	4.7 MΩ 5%	344665

Reference	Description		Part No.
	SHAPING AMPLIFIER PC BOARD (CONTINUED)		
R351	Resistor, MF	200 kΩ 1%	341529
R352	Resistor, MF	634 kΩ 1%	342577
R353	Resistor, Var.	1 kΩ 10% 1 W	311256
R354	Resistor, MF	14.3 kΩ 1%	341415
R355	Resistor, MF	2.49 kΩ 1%	341338
R356	Resistor, MF	34.8 kΩ 1%	341452
R357	Resistor, MF	523 kΩ 1%	342569
R358	Resistor, Comp.	4.7 MΩ 5%	344665
R359	Resistor, MF	162 kΩ 1%	341520
R360	Resistor, MF	806 kΩ 1%	342587
R361	Resistor, MF	10 kΩ 1%	341400
R362	Resistor, MF	2.74 kΩ 1%	341342
R363	Resistor, Var.	1 kΩ 10% 1 W	311256
R364	Resistor, MF	127 kΩ 1%	341510
R365	Resistor, MF	604 kΩ 1%	342575
RT301	Thermistor	100 Ω 10%	325005
	REAR PANEL, SUB PANEL, CHOPPER SOCKET		
C401	Capacitor, Mylar	100 nF 10% 50 V	234046
C402	Capacitor, Mylar	100 nF 10% 50 V	234046
F401	Fuse	0.1 Amp 220 V OR	545534
F401	Fuse	0.2 Amp 117 V	545508
G401	Chopper, Special		540127
J401	Receptacle		479119
M401	Meter & Scale		554294
R401	Resistor, Var.	5 kΩ 20% 2 W	311270
S401	Switch, Pushbutton		465154
S402	Switch, Slide		465134
S403	Switch		465212
T401	Power Transformer		446066
	DIGITAL CONTROL PC BOARD		
A604	Op. Amp.	LM301AN	535012
A605	Op. Amp.	LM301AN	535012
C606	Capacitor, Cer.	10 nF 100 V	224119
C607	Capacitor, Cer.	10 nF 100 V	224119
CR602	Diode, Zener	1N5236B (7.5 V 1%)	530087

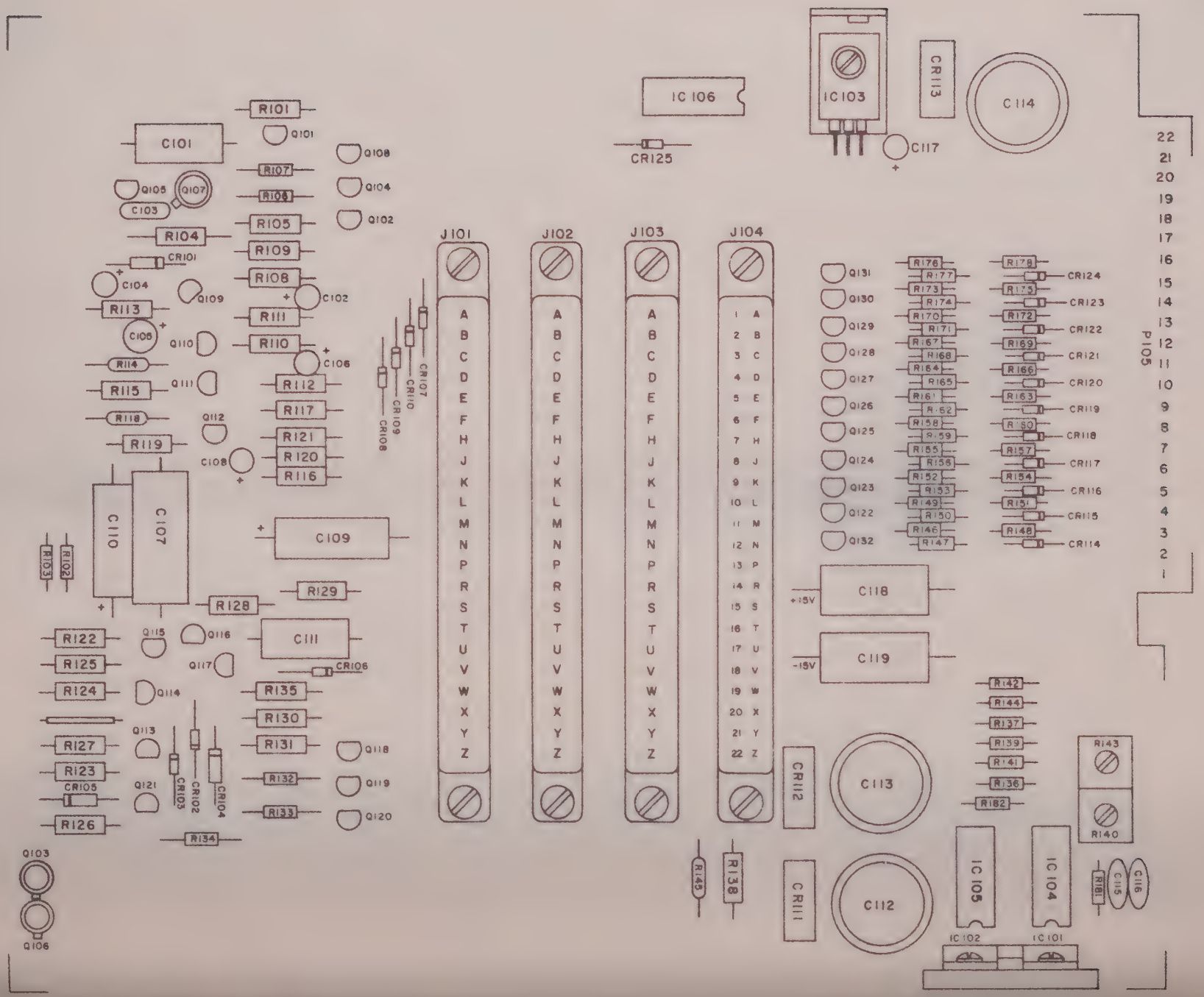
Reference	Description		Part No.
	DIGITAL CONTROL PC BOARD (CONTINUED)		
CR604	Diode, Zener	1N5227B (3.6 V 5%)	530095
CR605	Diode, Zener	1N5227B (3.6 V 5%)	530095
IC601	Integrated Circuit	SN74L10N (NAND Gate)	534029
IC602	Integrated Circuit	SN74L00N (NAND Gate)	534002
IC603	Integrated Circuit	CD4002AE (NAND Gate)	534044
IC604	Integrated Circuit	CD4002AE (NAND Gate)	534044
IC605	Integrated Circuit	SN74L00N (NAND Gate)	534002
IC606	Integrated Circuit	CD4016AE (Switch)	534007
IC607	Integrated Circuit	SN74L00N (NAND Gate)	534002
Q602	Transistor, FET	2N5653	528056
Q603	Transistor, FET	2N5653	528056
Q605	Transistor, FET	2N5653	528056
Q607	Transistor, PNP	2N3905	528025
Q608	Transistor, PNP	2N3905	528025
Q609	Transistor, FET	2N5653	528056
Q610	Transistor, PNP	2N3905	528025
R603	Resistor, Comp.	4.7 kΩ 5%	344365
R604	Resistor, Comp.	4.7 kΩ 5%	344365
R606	Resistor, Comp.	4.7 kΩ 5%	344365
R608	Resistor, Comp.	4.7 kΩ 5%	344365
R609 through R612	Resistor, Comp.	100 kΩ 5%	344500
R613	Resistor, Comp.	15 kΩ 5%	344417
R618	Resistor, Comp.	100 kΩ 5%	344500
R623	Resistor, Comp.	100 kΩ 5%	344500
R624	Resistor, Comp.	10 kΩ 5%	344400
R625	Resistor, Comp.	4.7 kΩ 5%	344365
R632	Resistor, Var.	200 Ω 10% 1 W	311269
R633	Resistor, MF	2.05 kΩ 1%	341330
R635	Resistor, MF	953 Ω 1%	341294
R636	Resistor, MF	16.5 kΩ 1%	341421
R637	Resistor, MF	13 kΩ 1%	341411
R638	Resistor, MF	11.5 kΩ 1%	341406
R639	Resistor, MF	33.2 kΩ 1%	341450
R640	Resistor, MF	80.6 kΩ 1%	341487
R641	Resistor, Comp.	10 kΩ 5%	344400
R642	Resistor, Comp.	10 kΩ 5%	344400
R643	Resistor, MF	9.76 kΩ 1%	341395
R644	Resistor, Var.	2 kΩ 10% 1 W	311264
R645	Resistor, Var.	100 Ω 10% 1 W	311383
	COUNTER PC BOARD		
C1201	Capacitor, Elec.	200 µF +75/-10% 6 V	283147

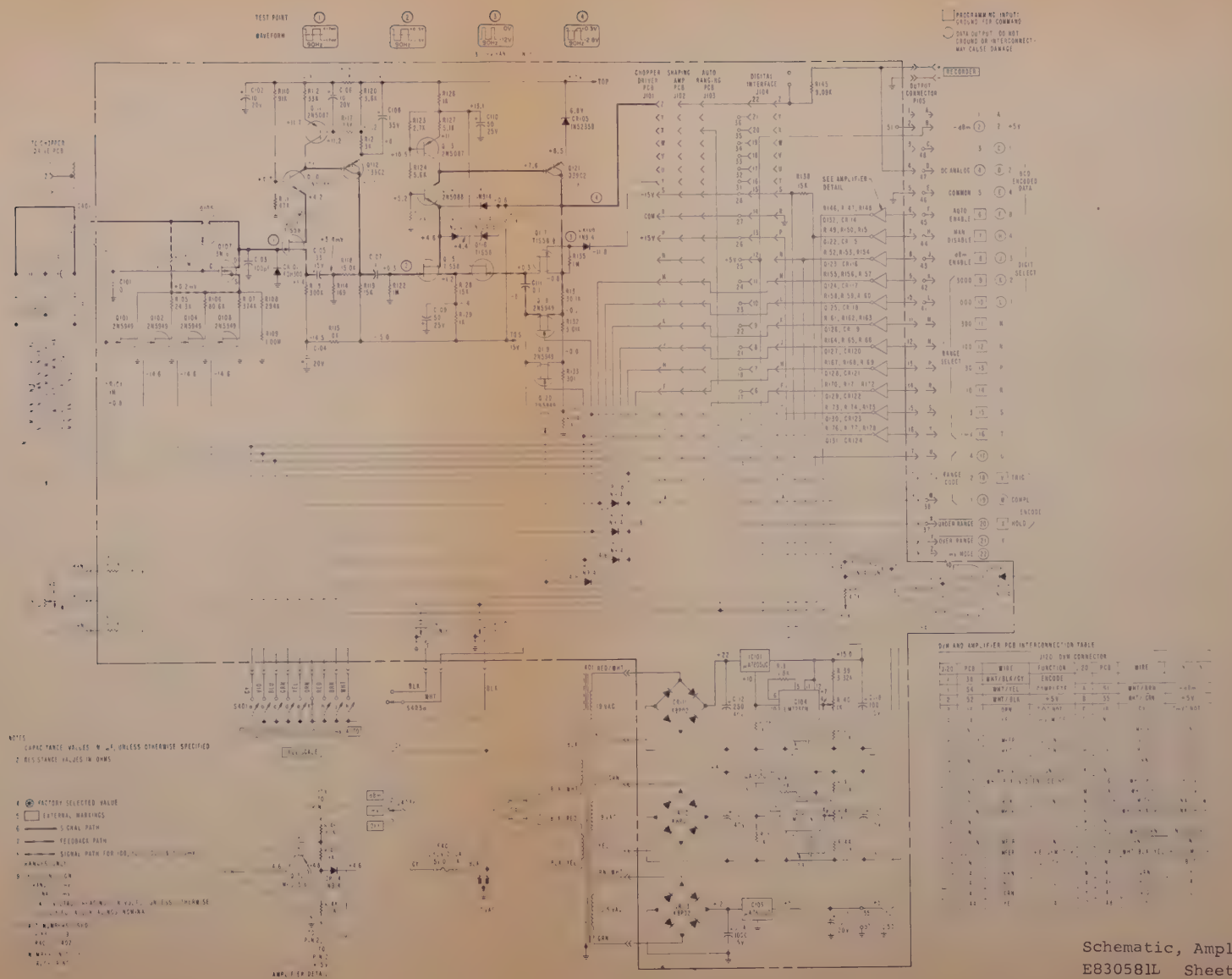
Reference		Description	Part No.
		COUNTER PC BOARD (CONTINUED)	
C1202*	Capacitor, Mica	120 pF 5% 500 V	200002
C1202*	Capacitor, Mica	56 pF 5% 500 V	200030
C1202*	Capacitor, Mica	150 pF 5% 500 V	200032
C1202*	Capacitor, Mica	91 pF 5% 500 V	200035
C1202*	Capacitor, Mica	33 pF 5% 500 V	200049
	*One of the above selected during calibration		
C1203	Capacitor, Var.	4.5 - 50 pF 250 V	281009
C1204	Capacitor, Mica	33 pF 5% 500 V	200049
C1205	Capacitor, Mylar	10 nF 20% 250 V	234085
C1206	Capacitor, Mylar	100 nF 20% 250 V	234080
C1207	Capacitor, Cer.	33 pF 10% 100 V	224218
C1208	Capacitor, Elec.	47 µF 20% 10 V	283219
C1209	Capacitor, Elec.	10 µF 20% 20 V	283205
CR1201	Diode, Zener	1N5234B (6.2 V 5%)	530093
CR1202	Diode, Zener	1N5234B (6.2 V 5%)	530093
CR1203	Diode, Sil.	1N914	530058
CR1204	Diode, Sil.	1N914	530058
IC1201	Integrated Circuit	SN74L00N (NAND Gate)	534002
IC1202	Integrated Circuit	MK5002P (Decade Counter)	534024
J1201	Connector, PC	44 Position (Dual 22)	479259
J1202	Connector, PC	6 Position	479277
J1203	Connector, PC	6 Position	479277
J1204	Connector, PC	6 Position	479277
Q1201 through Q1208	Transistor, PNP	MPS-6516	528037
Q1209	Transistor, NPN	MPS-6507	528070
Q1210	Transistor, NPN	MPS-6512	528059
Q1211	Transistor, NPN	MPS-6512	528059
Q1212	Transistor, NPN	MPS-6512	528059
Q1213	Transistor, PNP	2N5087	528042
Q1214	Transistor, NPN	MPS-6512	528059
Q1215 through Q1218	Transistor, PNP	2N5087	528042
Q1219	Transistor, NPN	MPS-6512	528059
Q1220	Transistor, Unij.	MPU-131	528062
Q1221 through Q1224	Transistor, PNP	2N5087	528042
R1201 through R1206	Resistor, Comp.	27 kΩ 5%	343441
R1207	Resistor, Comp.	2 kΩ 5%	343329

Reference		Description	Part No.
		COUNTER PC BOARD (CONTINUED)	
R1208	Resistor, Comp.	1 kΩ 5%	343300
R1209	Resistor, Comp.	5.1 kΩ 5%	343368
R1210	Resistor, Comp.	5.1 kΩ 5%	343368
R1211	Resistor, Comp.	75 kΩ 5%	343484
R1212	Resistor, Comp.	100 kΩ 5%	343500
R1213	Resistor, Comp.	100 kΩ 5%	343500
R1214	Resistor, Comp.	100 kΩ 5%	343500
R1215	Resistor, Comp.	27 kΩ 5%	343441
R1216 through R1220	Resistor, Comp.	5.1 kΩ 5%	343368
R1221	Resistor, Comp.	27 kΩ 5%	343441
R1222	Resistor, Comp.	3 kΩ 5%	343346
R1223	Resistor, Comp.	680 Ω 5%	343280
R1224	Resistor, Comp.	430 Ω 5%	343261
R1225	Resistor, Comp.	680 kΩ 5%	343580
R1226	Resistor, Comp.	100 kΩ 5%	343500
R1227	Resistor, Comp.	680 kΩ 5%	343580
R1228	Resistor, Comp.	5.1 kΩ 5%	343368
R1229	Resistor, Comp.	330 Ω 5%	343250
R1230	Resistor, Comp.	4.7 MΩ 5%	343665
R1231 through R1234	Resistor, Comp.	5.1 kΩ 5%	343368
R1235	Resistor, Comp.	430 Ω 5%	343261
		DISPLAY PC BOARD	
CR1301 through CR1304	Diode, Sil.	1N914	530058
DS1301	Numeric Display	MAN-3620	536805
DS1302	Numeric Display	MAN-3620	536805
DS1303	Numeric Display	MAN-3620	536805
DS1304	Lamp	583DX	545127
DS1305	Lamp	2200D	545120
DS1306	Lamp	2200D	545120
DS1307	Lamp	2200D	545120
DS1308	Numeric Display	MAN-3620	536805
DS1309	Lamp	2200D	545120
DS1310	Lamp	2200D	545120
DS1311	Lamp	2200D	545120
Q1301 through Q1307	Transistor, NPN	MPS-6512	528059
Q1308 through Q1311	Transistor, FET	MPS-A12	528052

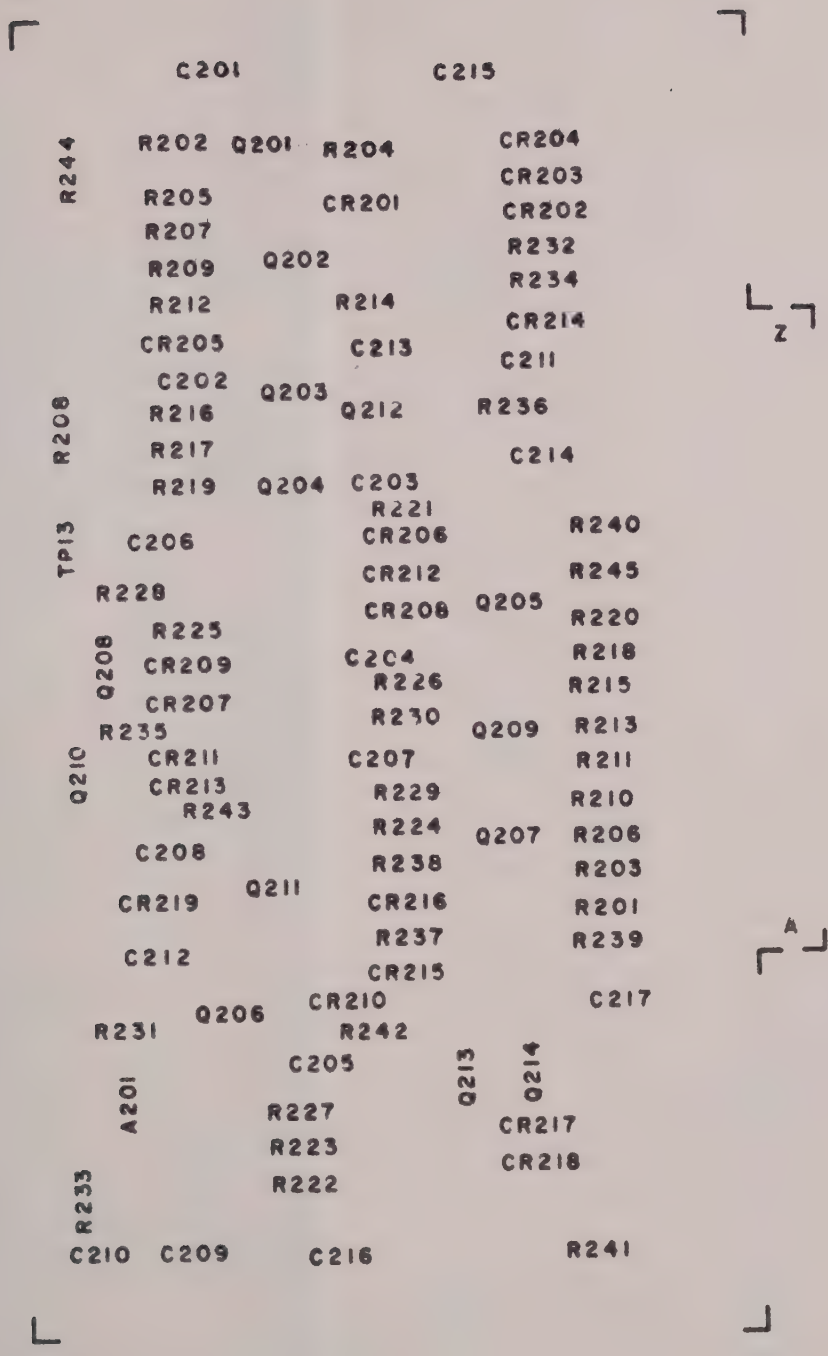
Reference	Description		Part No.
	DISPLAY PC BOARD (CONTINUED)		
Q1312	Transistor, PNP	2N5087	528042
R1301 through R1307	Resistor, Comp.	47 Ω 5%	343165
R1308 through R1311	Resistor, Comp.	27 kΩ 5%	343441
R1312	Resistor, Comp.	33 Ω 5%	343150
	A/D CONVERTER PC BOARD		
A1401	Op. Amp.	LM310	535005
A1402	Op. Amp.	LM301AN	535012
A1403	Op. Amp.	LM310	535005
A1404	Op. Amp.	LM311	535006
C1401	Capacitor, Elec.	1 µF 10% 35 V	283216
C1402	Capacitor, Elec.	1 µF 10% 35 V	283216
C1403	Capacitor, PC	0.1 µF 10% 50 V	234115
C1404	Capacitor, Cer.	33 pF 5% 500 V	224139
C1405	Capacitor, Elec.	1 µF 10% 35 V	283216
C1406	Capacitor, PC	0.1 µF 10% 50 V	234115
C1407	Capacitor, Mica	100 pF 5% 300 V	205006
CR1401	Diode, Zener	1N821 (6.2 V 5%)	530050
CR1402	Diode, Zener	1N821 (6.2 V 5%)	530050
CR1403	Diode, Sil.	1N914	530058
CR1404	Diode, Sil.	1N914	530058
CR1405	Diode, Sil.	1N914	530058
IC1401	Integrated Circuit	CD4016AE (Switch)	534007
IC1402	Integrated Circuit	CD4013AE (Binary)	534021
IC1403	Integrated Circuit	CD4011AE (NAND Gate)	534022
IC1404	Integrated Circuit	CD4001AE (NOR Gate)	534023
Q1401	Transistor, FET	Selected	528068
R1401	Resistor, MF	30.9 kΩ 1%	341447
R1402	Resistor, MF	30.9 kΩ 1%	341447
R1403	Resistor, MF	5.49 kΩ 1%	341371
R1404	Resistor, MF	5.49 kΩ 1%	341371
R1405	Resistor, Var.	5 kΩ 20% 0.5 W	311293
R1406	Resistor, MF	1.15 kΩ 1%	341306
R1407	Resistor, MF	200 kΩ 1%	341529
R1408	Resistor, Var.	5 kΩ 20% 0.5 W	311293
R1409	Resistor, Comp.	330 Ω 5%	343250
R1410	Resistor, Comp.	10 kΩ 5%	343400
R1411	Resistor, MF	1.15 kΩ 1%	341306

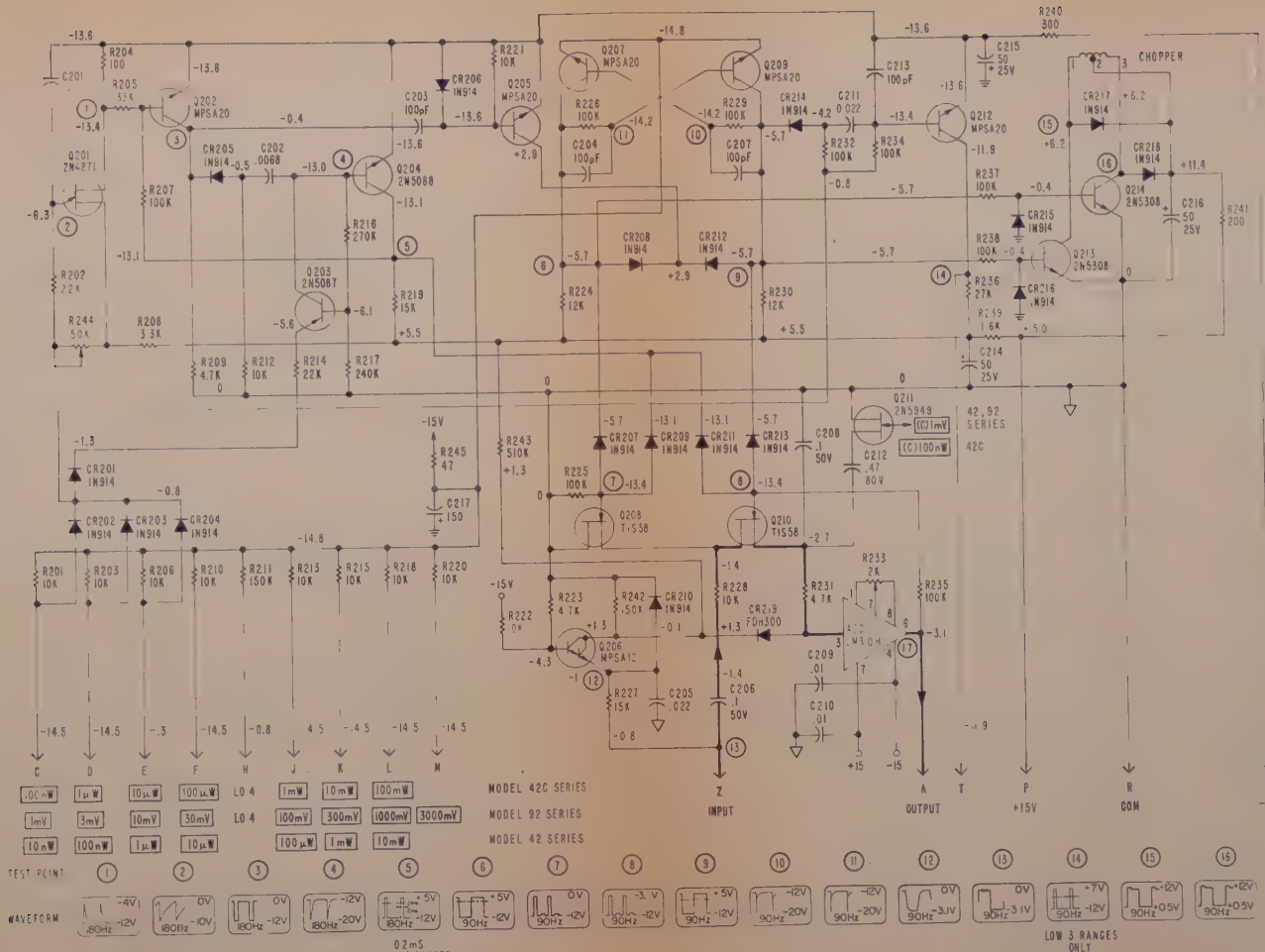
Reference	Description		Part No.
	A/D CONVERTER PC BOARD (CONTINUED)		
R1412	Resistor, Comp.	27 kΩ 5%	343441
R1413	Resistor, Comp.	4.7 MΩ 5%	343665
R1414	Resistor, Comp.	680 Ω 5%	343280
R1415	Resistor, Comp.	27 kΩ 5%	343441
R1416	Resistor, Comp.	5.1 kΩ 5%	343368
R1417	Resistor, Comp.	10 kΩ 5%	343400
R1418	Resistor, Comp.	4.7 MΩ 5%	343665
R1419	Resistor, Comp.	1 MΩ 5%	343600
R1420	Resistor, Comp.	47 kΩ 5%	343465


IC 106
CR125
IC103
CR113
C114
C117
J101
J102
J103
J104
P105
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
R101
Q101
C101
R107
Q108
Q105
Q107
Q104
C103
R106
Q102
R104
R105
R109
CR101
C104
R108
C102
Q109
R113
R111
C105
Q110
R110
C106
R114
R115
Q111
R112
R118
R117
Q112
R119
R121
R120
C108
R116
C110
C107
C109
R103
R102
R129
R128
R122
Q115
Q116
C111
R125
Q117
CR106
R124
Q114
R135
R130
R127
Q113
R131
Q118
R123
CR102
CR103
CR104
Q121
R132
Q119
CR105
R133
Q120
R126
R134
Q103
Q106
CR107
CR110
CR109
CR108
Q131
Q130
Q129
Q128
Q127
Q126
Q125
Q124
Q123
Q122
Q132
R176
R177
R173
R174
R170
R171
R167
R168
R164
R165
R161
R162
R158
R159
R155
R156
R152
R153
R149
R150
R146
R147
R178
R175
R172
R169
R166
R163
R160
R157
R154
R151
R148
CR124
CR123
CR122
CR121
CR120
CR119
CR118
CR117
CR116
CR115
CR114
+15V
C118
-15V
C119
R142
R144
R137
R139
R141
R136
R182
R143
R140
CR112
C113
CR111
C112
R145
R138
IC 105
IC 104
R181
C115
C116
IC 102
IC 101



Schematic, Amplifier
E83058lL Sheet 1 of 3


C201
C215
R244
R202
Q201
R204
CR204
CR203
R205
CR201
CR202
R207
R232
R209
Q202
R234
R212
R214
CR214
Z
CR205
C213
C211
C202
Q203
R208
R216
Q212
R236
R217
C214
R219
Q204
C203
R221
TP13
C206
CR206
R240
CR212
R245
R228
CR208
Q205
R220
R225
R218
Q208
CR209
C204
R226
R215
CR207
R230
Q209
R213
R235
CR211
C207
R211
Q210
CR213
R229
R210
R243
R224
Q207
R206
C208
R238
R203
Q211
CR219
CR216
R201
A
R237
R239
C212
CR215
CR210
C217
Q206
R231
R242
C205
Q213
Q214
A201
R227
CR217
R223
CR218
R233
R222
C210
C209
C216
R241



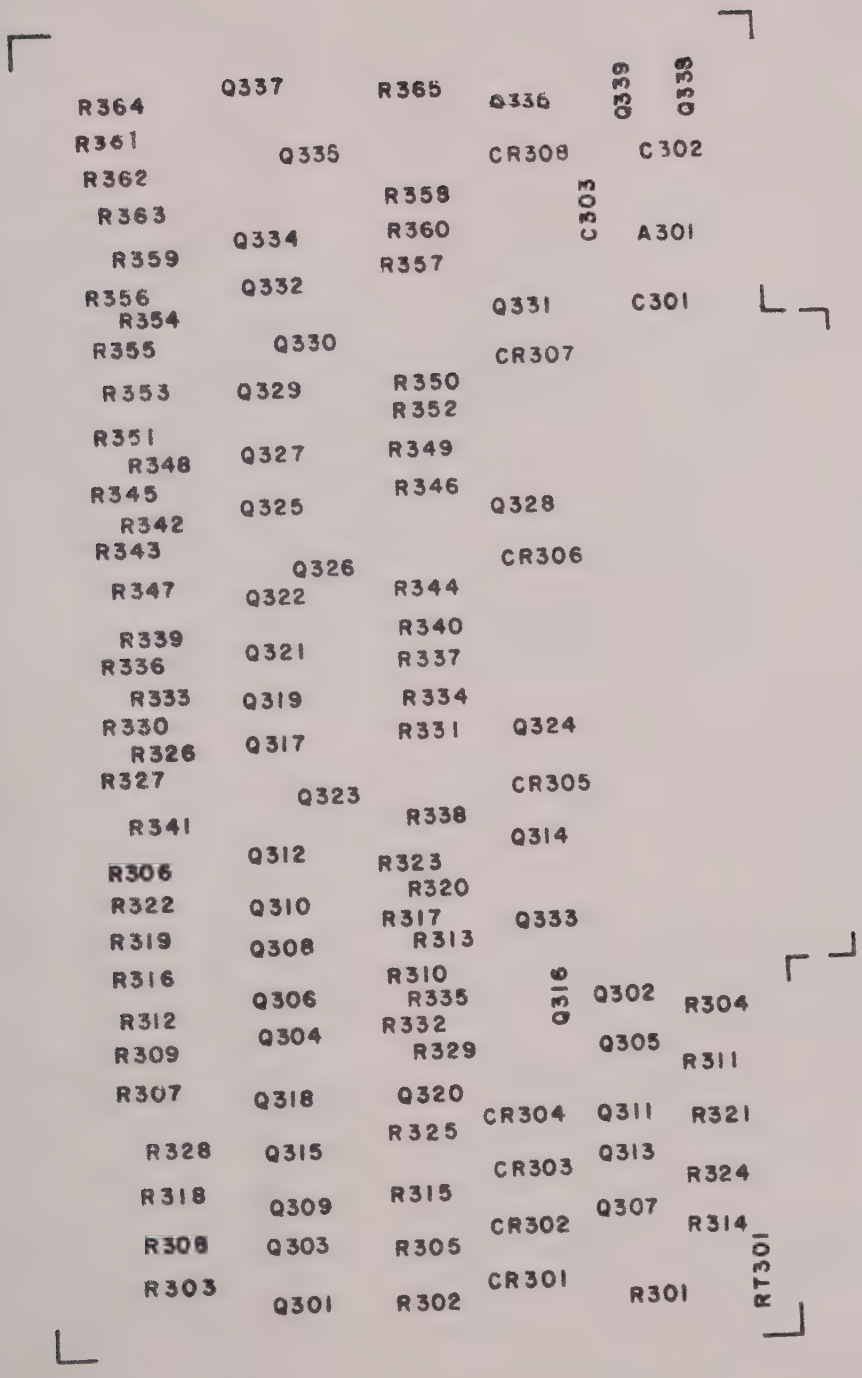
P101
CONNECTS TO J101
ON AMP. BD 566565

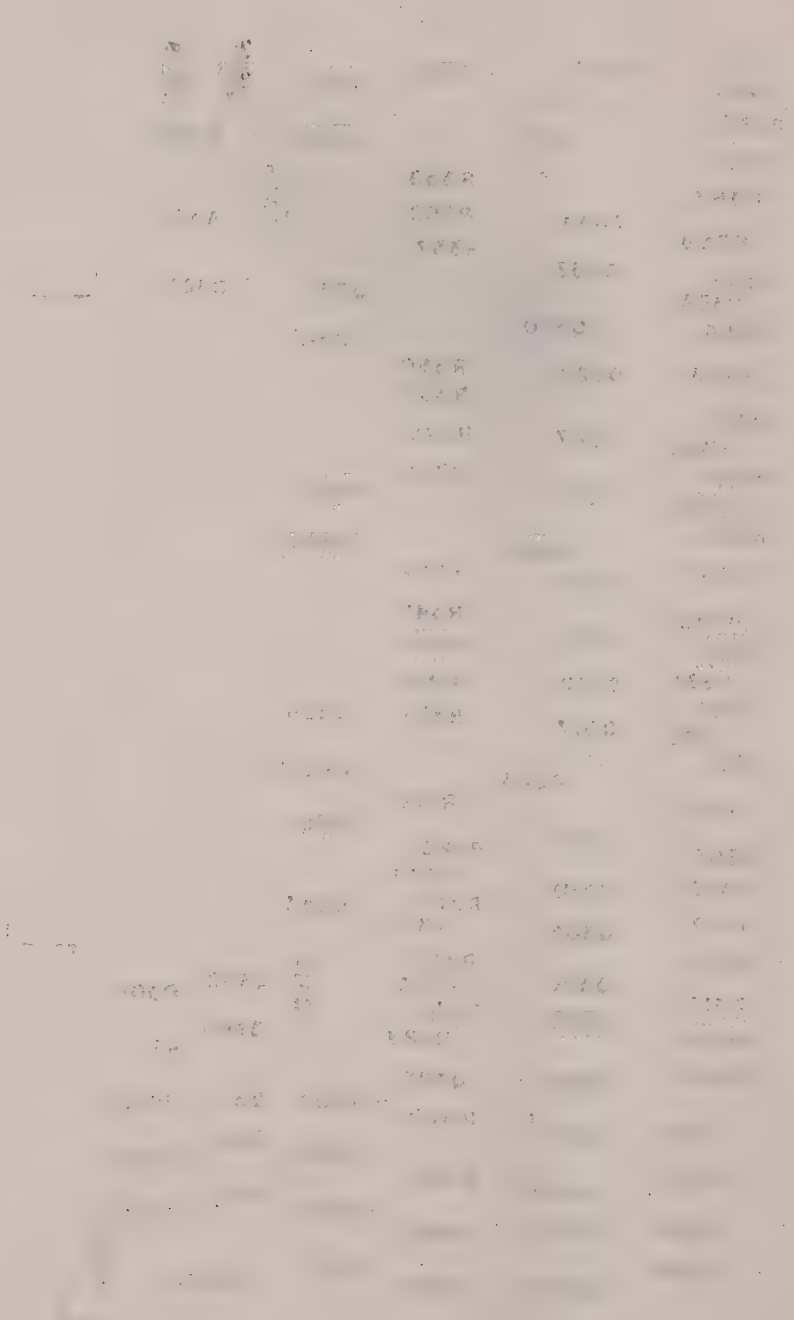
INSTRUMENT	SCHEMATIC
42B	830636
42BB	830658 SHT 1
42BD	830592 SHT 1
42C	830636
42CD	830592 SHT 1
42CB	830658 SHT 1

NOTES

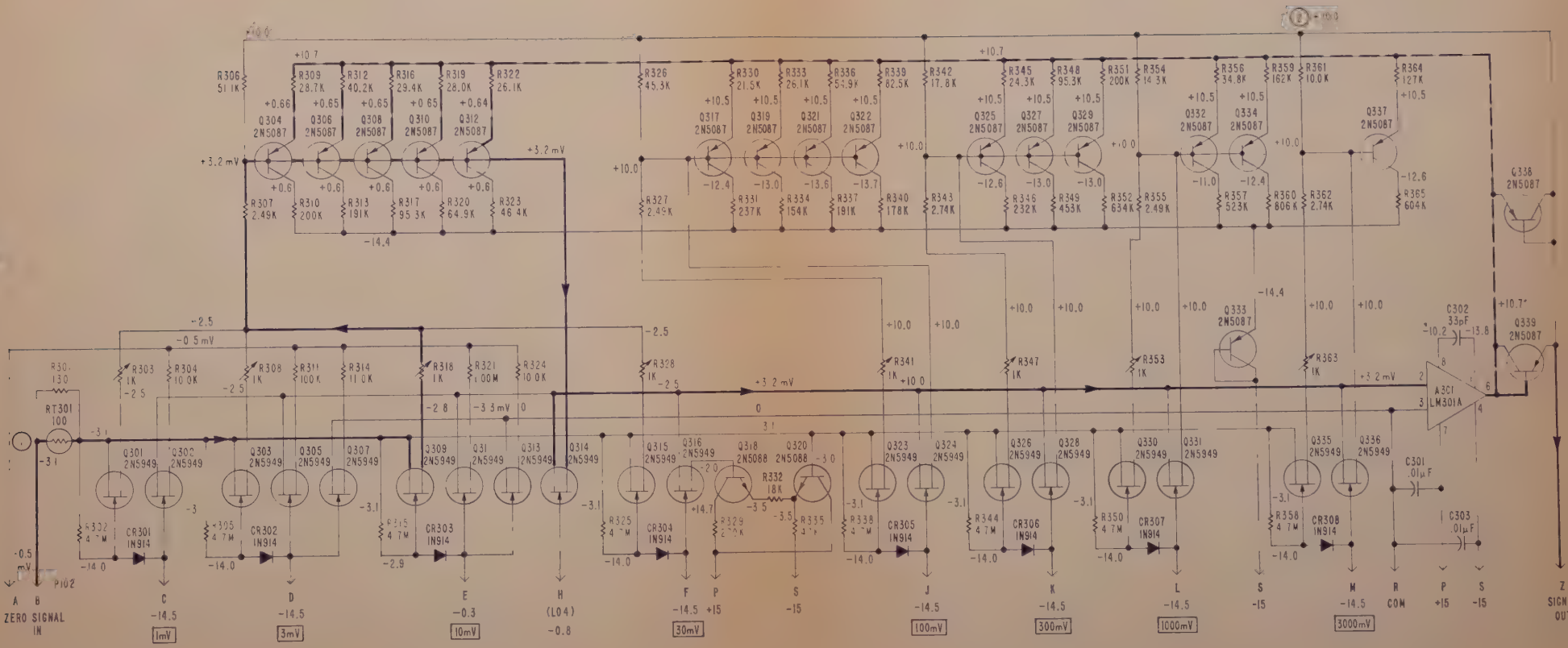
1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS.
3. ☐ EXTERNAL MARKINGS.
4. ▽ COMMON
5. ——— SIGNAL PATH
6. TEST CONDITIONS
   10mV RANGE, 10mV SIGNAL — 42, 92 SERIES
   10 μW RANGE, 10 μW SIGNAL — 42C ONLY
   ALL VOLTAGES NOMINAL. ALL READINGS IN VOLTS, UNLESS OTHERWISE SPECIFIED.
8. LAST NUMBERS USED:
   R245 C217 Q214 CR219 A201

Schematic, Chopper Driver
D830581N Sheet 3 of 3

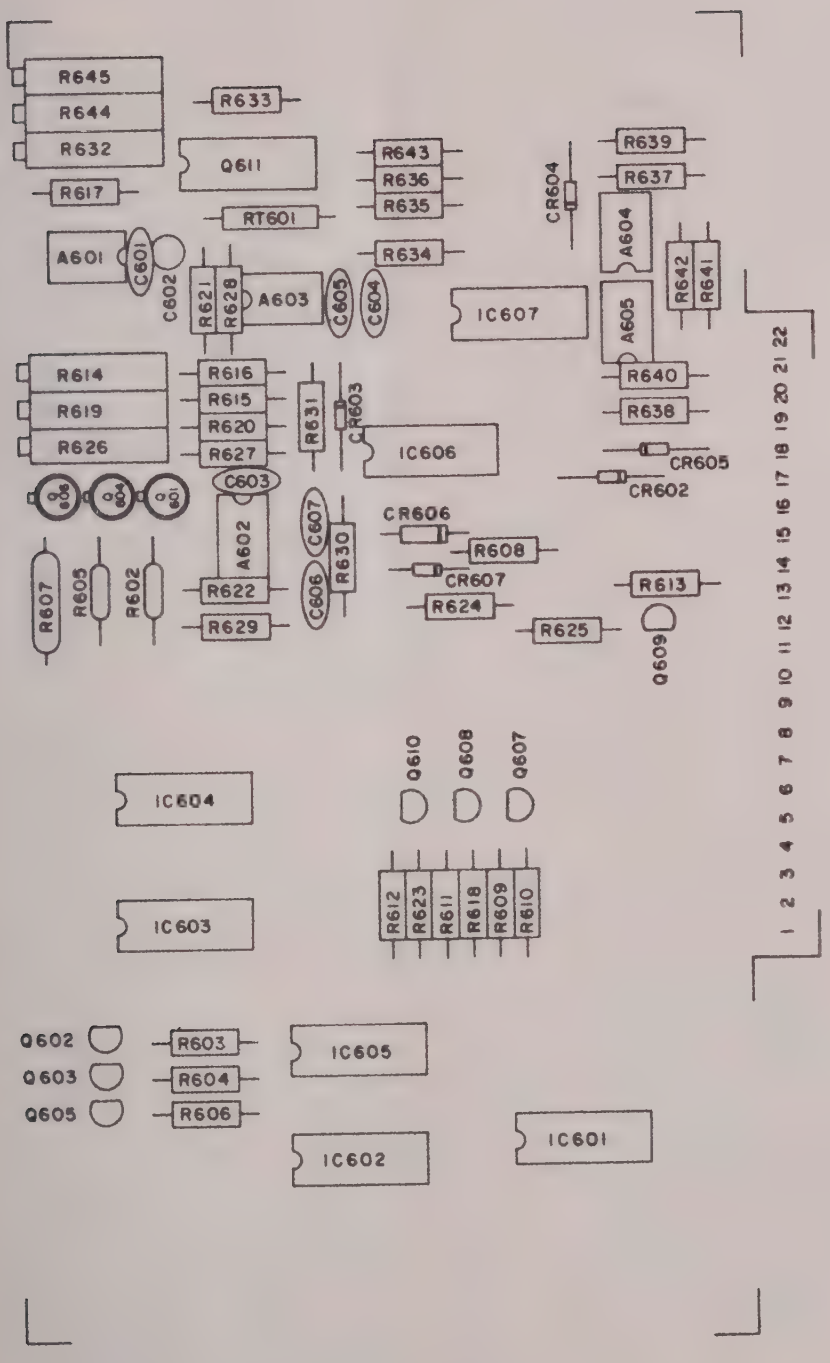

R364
Q337
R365
Q336
Q339
Q338
R361
Q335
CR308
C302
R362
R358
R363
C303
Q334
R360
A301
R359
R357
R356
Q332
Q331
C301
R354
R355
Q330
CR307
R353
Q329
R350
R352
R351
R348
Q327
R349
R345
R346
Q325
Q328
R342
R343
Q326
CR306
R347
Q322
R344
R339
R340
R336
Q321
R337
R333
Q319
R334
R330
Q317
R331
Q324
R326
R327
Q323
CR305
R341
R338
Q314
Q312
R306
R323
R320
R322
Q310
R317
Q333
R319
Q308
R313
R316
R310
Q316
Q302
R304
Q306
R335
R312
R332
Q304
Q305
R309
R329
R311
R307
Q318
Q320
CR304
Q311
R321
R328
Q315
R325
CR303
Q313
R324
R318
Q309
R315
Q307
CR302
R314
R308
Q303
R305
RT301
CR301
R303
Q301
R302
R301

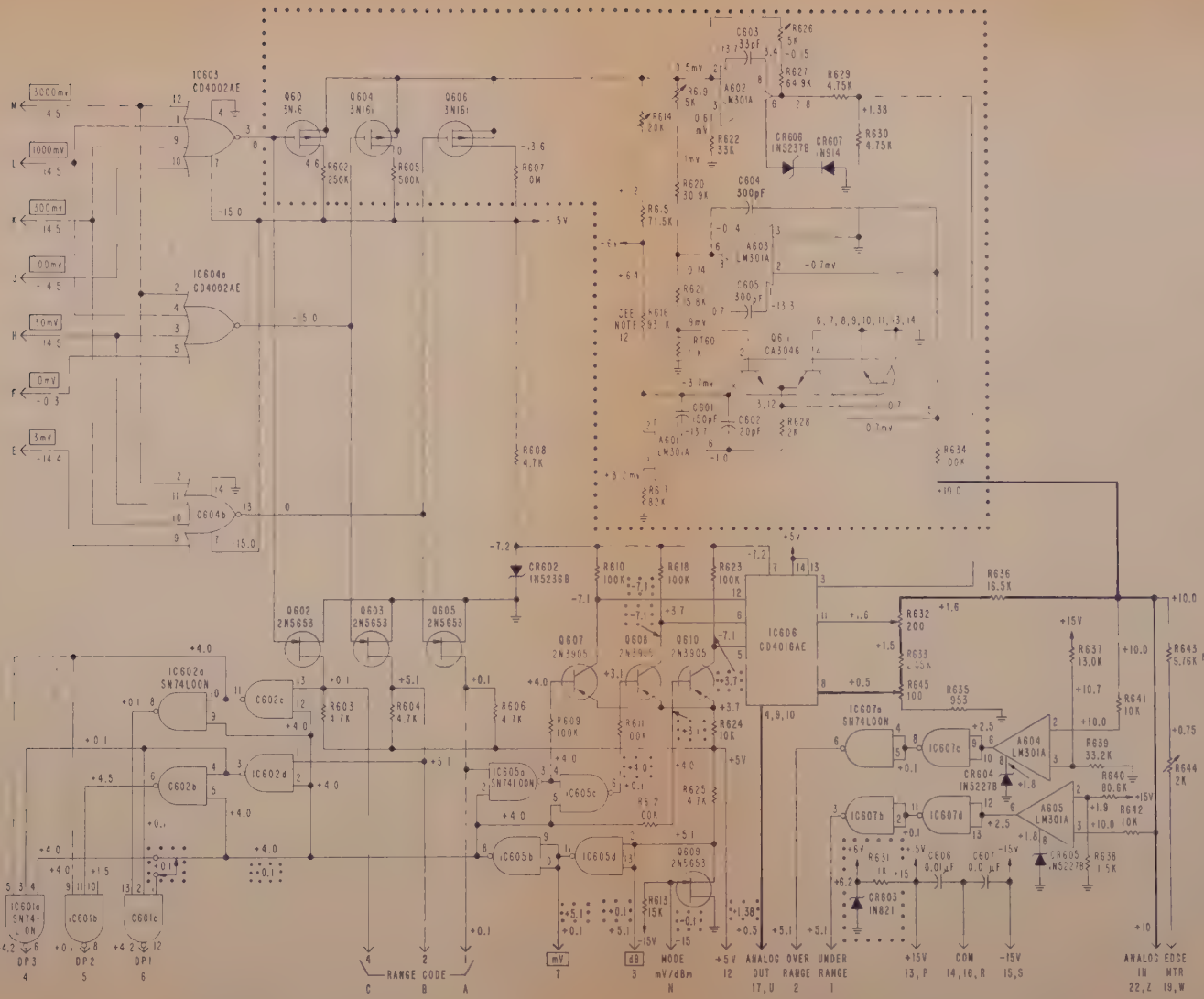


NOTES:
1. RESISTANCE VALUES IN OHMS.
2. SIGNAL PATH ——
3. FEEDBACK PATH ——
4. [ ] EXTERNAL MARKINGS
5. LAST NUMBER USED:
R365 C303 Q339 CR308



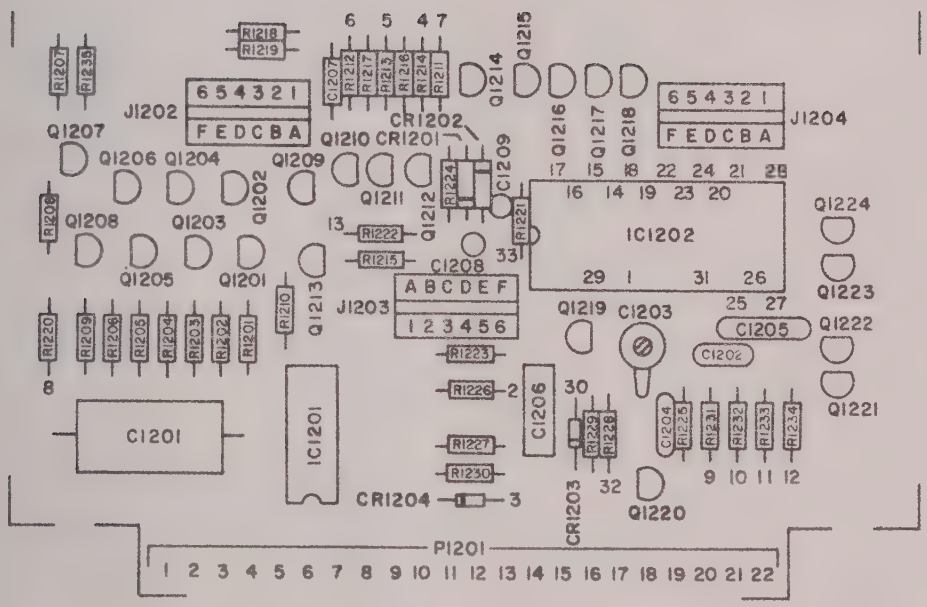
Schematic, Shaping Amp.
D830456L Sheet 3 of 3


R645
R644
R632
R633
Q611
R643
R636
R635
R639
R637
CR604
A604
R617
RT601
A601
C601
C602
R621
R628
A603
C605
C604
R634
IC607
A605
R642
R641
R614
R619
R626
R616
R615
R620
R627
R631
CR603
IC606
R640
R638
CR605
CR602
C603
A602
C607
C606
R630
CR606
R608
CR607
R624
R625
R613
Q609
R607
R605
R602
R622
R629
Q610
Q608
Q607
IC604
IC603
R612
R623
R611
R618
R609
R610
Q602
Q603
Q605
R603
R604
R606
IC605
IC602
IC601
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

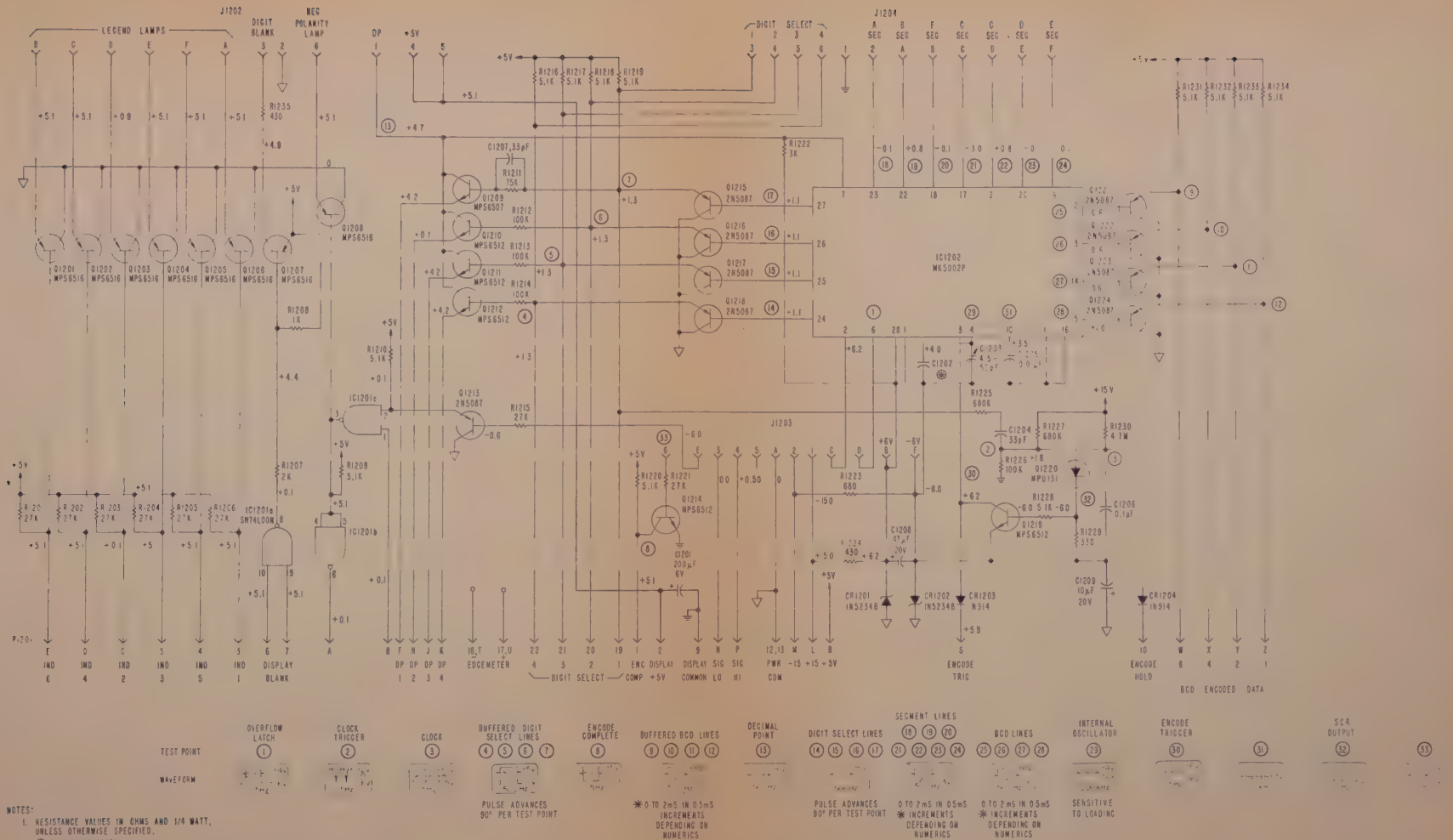


NOTES:
1. RESISTANCE VALUES IN OHMS.
2.
3. EXTERNAL MARKINGS
4. SIGNIFIES COMPONENTS ADDED FOR 928D-09.
5. DENOTES JUMPER USED ON MODEL 928D WITH dB OPTION.
6. SIGNAL PATH
7. TEST CONDITIONS:
   RANGE ; 10mV INPUT ; 10mV
8. READINGS INSIDE TAKEN WITH dBm MODE ENERGIZED.
9. READINGS OUTSIDE TAKEN WITH mV MODE ENERGIZED.
10. VOLTAGE READINGS IN VOLTS, UNLESS OTHERWISE SPECIFIED
11. LAST NUMBERS USED:
    R645 C607 C611 CR607
12. ON 928D-10 THIS VALUE IS 73.2K .

Schematic, Digital Control
D830581F Sht. 2 of 3



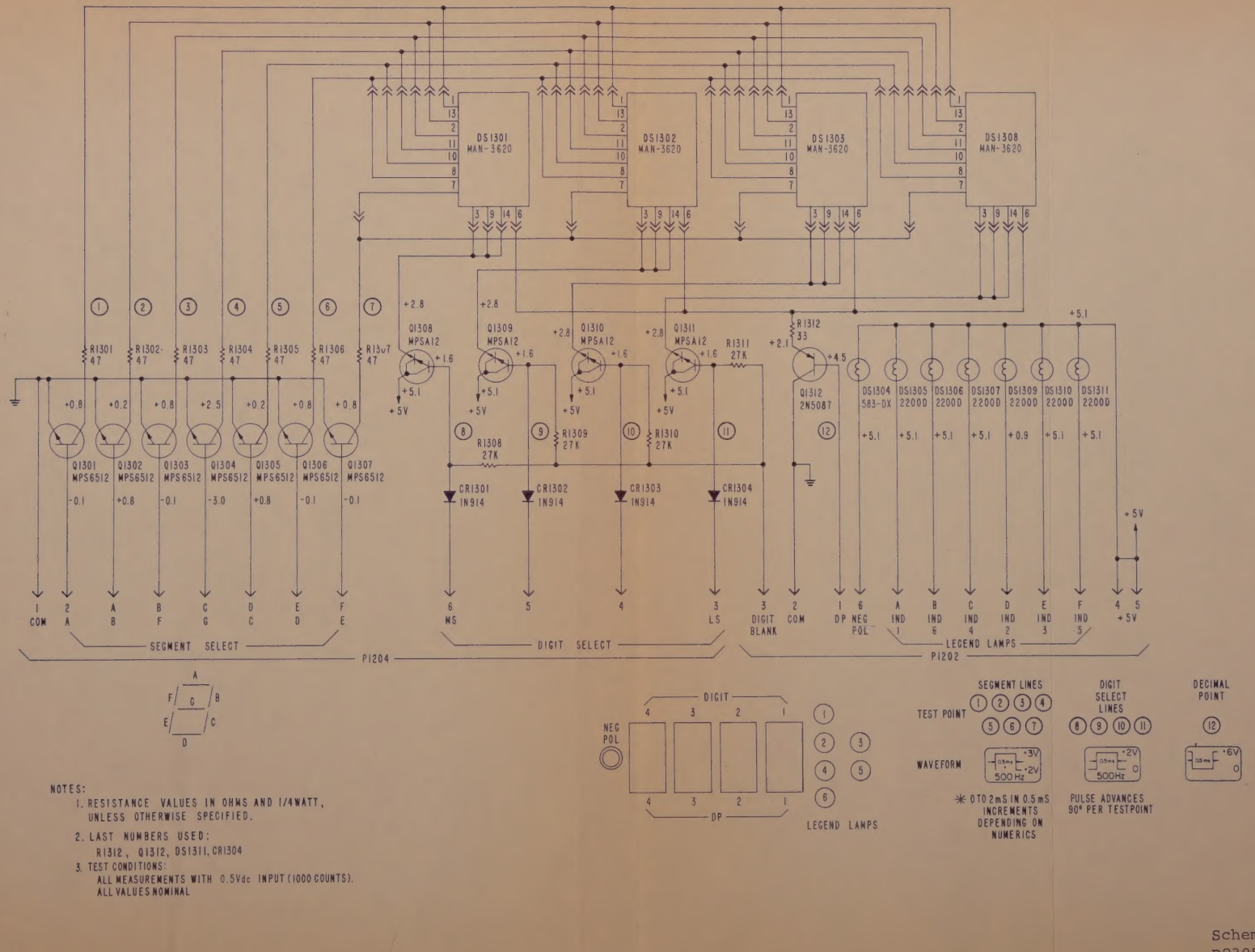
NOTE:
NUMBERS WITHOUT A LETTER PREFIX
DENOTE A SCHEMATIC TEST POINT.



NOTES:
1. RESISTANCE VALUES IN OHMS AND 1/4 WATT, UNLESS OTHERWISE SPECIFIED.
2. ⊛ FACTORY SELECTED
3. TEST CONDITIONS:
   ALL MEASUREMENTS MADE WITH +0.5V INPUT. ADJ R1405 TO +1000 COUNTS
   ALL VALUES NOMINAL
4. LAST NUMBERS USED:
   R1235 C1209 Q1224
5. ▽ COMMON

Schematic, Counter Board
E830546G Sht 1 of 3

Q1301 R1301
Q1302 R1302
Q1303 R1303
Q1304 R1304
Q1305 R1305
Q1306 R1306
Q1307 R1307
P1204
1 2 3 4 5 6
Q1308
Q1309
Q1310
Q1311
DS1305
DS1309 DS1310
2 3
DS1307 DS1311
4 5
DS1306
6
P1202
1 2 3 4 5 6
DS1301
DS1302
DS1303
DS1304
DS1308
CR1301
R1308
CR1302
R1309
CR1303
R1310
CR1304
R1311
R1312
Q1312



NOTES:

1. RESISTANCE VALUES IN OHMS AND 1/4WATT, UNLESS OTHERWISE SPECIFIED.
2. LAST NUMBERS USED: R1312, Q1312, DS1311, CR1304
3. TEST CONDITIONS: ALL MEASUREMENTS WITH 0.5Vdc INPUT (1000 COUNTS). ALL VALUES NOMINAL

Schematic, Display Board
D830546G Sheet 2 of 3

A D D E N D U M

PLEASE CHANGE ALL REFERENCES TO WEINSCHEL POWER DIVIDER 1506 TO:

WEINSCHEL POWER DIVIDER 1870A

ADDENDUM

PLEASE CHANGE ALL REFERENCES TO WEINSCHEL POWER DIVIDER 1506 TO:

WEINSCHEL POWER DIVIDER 1870A